Al'adzkiya International of Computer Science and Information Technology (AIoCSIT) Journal
Vol. 7, No. 1, April 2026, pp. 24~36
ISSN: 2722-0001, DOI : 10.55311/aiocsit.v7i1.380

Development of an Augmented Reality (AR) Anatomy Application to Enhance Practical Skills in Vocational Health Education

Yoga Sahria[1], Edwina Nur Utami[2], Christina Ismaniati[3], Putu Sudira[4]
[1,4]Technology and Vocational Education Study Program, Universitas Negeri Yogyakarta, Indonesia
[2]Nursing Study Program, STIKES AL-ISLAM Yogyakarta, Indonesia
[3]Educational Technology Program, Universitas Negeri Yogyakarta, Indonesia

ABSTRACT

Vocational health education, particularly diploma-level nursing programs, faces challenges in anatomy learning that still rely on conventional methods using mannequin models and two-dimensional atlases. This study aimed to develop and evaluate an Android-based Augmented Reality (AR) anatomy application designed for vocational nursing students at STIKES Al Islam Yogyakarta. The development process employed the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). Usability evaluation was conducted using the User Experience Questionnaire (UEQ) and the System Usability Scale (SUS) involving 40 students. The UEQ results showed an overall score of 1.80 (Excellent category), with the Novelty scale achieving the highest score (1.93) and the Efficiency scale the lowest (1.68). The average SUS score was 81.3, categorized as Excellent/Grade A. Effectiveness testing using pre-test and post-test assessments demonstrated an improvement in practical examination scores from an average of 55.4 to 81.1, with an N-gain score of 0.57 (moderate category). The findings indicate that the AR anatomy application is feasible for use and effective in improving the practical skills of vocational nursing students.

Keyword: ***Augmented Reality, Anatomy Application, Vocational Health Education, Skills***

Corresponding Author:
Yoga Sahria,
Graduate School, Technology and Vocational Education Study Program
Universitas Negeri Yogyakarta
Colombo No. 1, Karangmalang, Kelurahan Caturtunggal, Kecamatan Depok, Kabupaten Sleman, Yogyakarta
Email: yoga.sahria@uny.ac.id

1. INTRODUCTION

Vocational education in the health sector, particularly in Diploma III (D3) Nursing programs, requires students to possess strong practical competencies and clinical skills as preparation for providing professional healthcare services [1]. One of the fundamental competencies that must be mastered is a comprehensive understanding of human anatomy, as anatomical knowledge serves as the primary foundation for various nursing procedures, including physical assessment, catheter insertion, intramuscular injection, intravenous therapy, and emergency care management [2]. A thorough understanding of the structure and function of human organs significantly influences the accuracy of clinical decision-making and patient safety [3]. However, current practice indicates that conventional anatomy learning methods, which still rely on static mannequins, two-dimensional atlases, image-based media, and lecture-based instruction, have not been fully effective in developing students' three-dimensional spatial understanding [4]. These limitations in learning media often cause students to experience difficulties in visualizing the actual shape, position, and interrelationships among body organs, resulting in less interactive learning processes and suboptimal comprehension of anatomical concepts [5]. In addition, the limited availability of teaching aids and the lack of direct practical experience remain significant challenges in improving the quality of anatomy education in vocational nursing programs.

STIKES Al Islam Yogyakarta, as an institution providing vocational nursing education, faces similar challenges in the teaching and learning process of anatomy and physiology [6]. Based on preliminary observations and interviews with practicum supervisors, it was found that more than 60% of Diploma III Nursing students experienced difficulties in accurately identifying the location, shape, and

interrelationships among body organs, particularly during anatomy and physiology practical sessions. This condition indicates that students' understanding of anatomical concepts remains largely theoretical and has not been fully integrated with the practical clinical skills required in professional healthcare settings [7]. The limited availability of interactive three-dimensional learning media, the continued use of conventional teaching aids, and the lack of opportunities for independent repetitive practice are considered major factors contributing to the low achievement of students' practical competencies [8]. In addition, learning methods that are predominantly lecturer-centered tend to reduce students' active engagement in exploring anatomical structures visually and comprehensively [9]. The impact of these challenges not only affects students' academic performance but also has the potential to reduce their readiness for clinical practice and professional work in healthcare services.

The advancement of Augmented Reality (AR) technology has created new opportunities for innovation in learning media within the healthcare sector [10–16], particularly in the study of human anatomy [17]. AR is a technology capable of integrating three-dimensional virtual objects into real-world environments in real time [18], thereby creating a more immersive [19], interactive [20], and contextual learning experience [21]. Unlike Virtual Reality (VR), which completely replaces the real environment with a virtual world [22],[23], AR maintains the real-world context while adding digital information layers such as 3D models, animations, and interactive visualizations that can be observed from multiple perspectives [24]. In the educational context, the implementation of AR technology is considered capable of increasing students' motivation and engagement in the learning process by providing a more attractive learning experience compared to conventional methods [25]. AR has also been shown to assist students in understanding complex concepts, improving spatial visualization abilities, and strengthening long-term information retention [26]. Through more realistic and interactive visualization of body organs, students can study anatomical structures more comprehensively, conduct independent exploration, and connect theoretical knowledge with clinical practice more effectively.

Several previous studies have developed Augmented Reality (AR) applications for anatomy learning at the university level with positive outcomes [27]. Research findings indicate that the use of AR can improve students' understanding of anatomical materials compared to conventional learning methods [28]. The implementation of AR has also been proven to enhance students' confidence in identifying anatomical structures through more interactive and visual learning experiences [29]. Nevertheless, the development of AR applications specifically designed for vocational nursing education in Indonesia, particularly those that consider the characteristics of the Diploma III curriculum and the profile of vocational students, remains very limited.

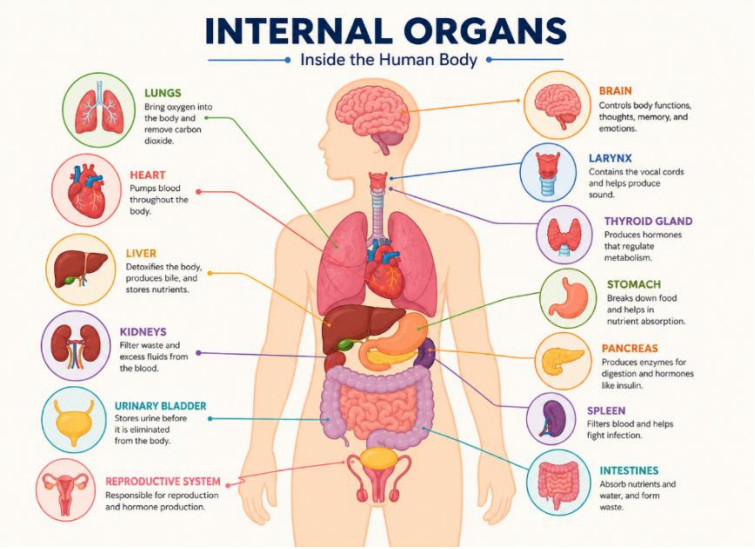

Figure 1. The Human Body

The novelty of this study lies in three main aspects that distinguish it from previous research. First, this study develops an Augmented Reality (AR) application customized to the curriculum of the Diploma III (D3) Nursing Program in Indonesia and aligned with the competency standards established

by Persatuan Perawat Nasional Indonesia (PPNI). Therefore, the learning materials presented are more relevant to the needs of vocational nursing education. Second, the developed application not only provides general visualization of human anatomy but also integrates anatomical content within the context of clinical nursing procedures frequently performed by students, such as physical assessment, injections, intravenous therapy, and other nursing procedures. This approach is expected to help students connect anatomical concepts with clinical practice in a more contextual and applicable manner. Third, this study employs a comprehensive usability and user experience evaluation using the internationally validated User Experience Questionnaire (UEQ) and System Usability Scale (SUS) instruments. As a result, the quality of the application can be assessed not only from technical aspects but also in terms of user comfort, effectiveness, efficiency, and satisfaction. Thus, this study is expected to produce an AR-based learning medium that is not only technologically innovative but also adaptive, contextual, and meaningful in supporting the improvement of vocational nursing students' competencies.

The objectives of this study are: (1) to develop an Augmented Reality (AR)-based anatomy application that meets the learning needs of Diploma III (D3) Nursing students at STIKES Al Islam Yogyakarta; (2) to evaluate the usability and user experience of the developed application using the User Experience Questionnaire (UEQ) and System Usability Scale (SUS) instruments; and (3) to measure the effectiveness of the application in improving students' practical skills and understanding of anatomy through the analysis of pre-test and post-test results. Through this study, the developed AR application is expected to become an innovative learning medium that is interactive, user-friendly, and effective in supporting the anatomy learning process in vocational nursing education.

2. RESEARCH METHOD

A. Research Design

This study employed a Research and Development (R&D) approach using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) [30]. The ADDIE model was selected because its systematic framework and continuous evaluation cycle are highly suitable for the development of technology-based learning media. The study was conducted at STIKES Al Islam Yogyakarta. The ADDIE model used in this study is presented below.

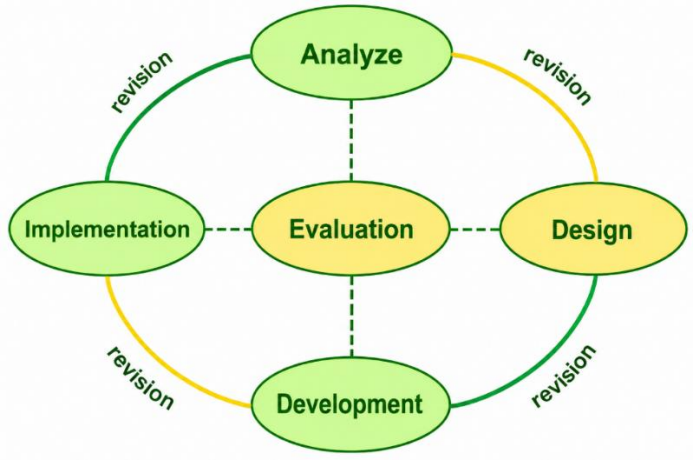

Figure 2. Model ADDIE

B. Research Participants

The research subjects consisted of 40 active students from the Diploma III (D3) Nursing Program at STIKES Al Islam Yogyakarta who were selected using purposive sampling. The inclusion criteria were: (1) registered as active students in the third or fifth semester; (2) possessing an Android smartphone with at least Android version 8.0 (Oreo); (3) having no prior experience using AR applications for anatomy learning; and (4) willing to participate in all stages of the study. The study also involved five expert validators, consisting of two nursing subject-matter experts, two learning media experts, and one usability expert.

Table 1. Characteristics of Research Respondents

Characteristics	Category	Frequency (n)	Percentage (%)
Gender	Male	16	40%
	Women	24	60%
Semester	Semester 3	22	55%
	Semester 5	18	45%
Smartphone Experience	>2 Year	37	92.5%
	1-2 Year	3	7.5%
Familiar AR	Yes	12	30%
	No	28	70%

C. ADDIE Development Stages

The Analysis phase included the identification of user needs through in-depth interviews with eight nursing lecturers and Focus Group Discussions (FGDs) involving 15 Diploma III (D3) Nursing students to identify the main challenges in anatomy and physiology learning. The analysis process focused on students' difficulties in understanding the spatial structure of body organs, the limitations of interactive visual media, and the need for more flexible and contextual independent learning. In addition, user characteristic analysis was conducted to examine students' digital technology skills and their readiness for the implementation of augmented reality-based learning media in the instructional process. Curriculum analysis was carried out on the Basic Biomedical Science and Anatomy and Physiology courses based on the intended learning outcomes and competency standards established by the Asosiasi Institusi Pendidikan Vokasi Keperawatan Indonesia. The results of this analysis served as the foundation for determining the learning content, application features, and instructional scenarios to be developed in the subsequent stages.

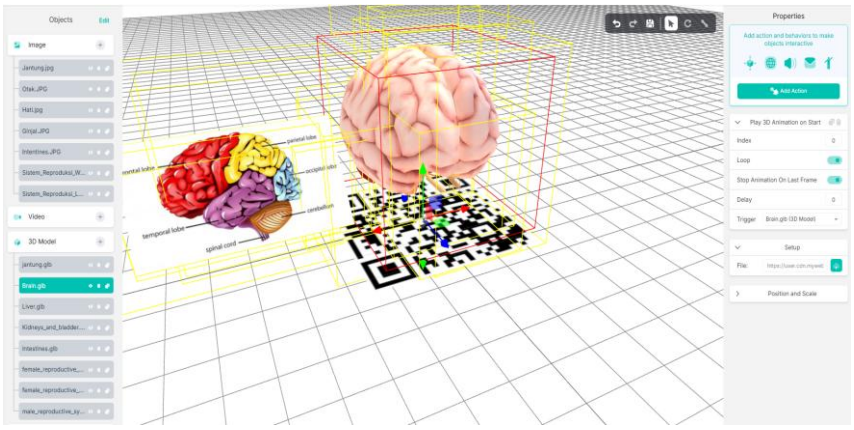

Figure 3. 3D Augmented Reality Design

The Design phase produced the application specifications based on the results of the user needs analysis and the learning objectives of nursing anatomy education. This phase included: (a) the development of interactive storyboards for the human anatomical system, illustrating the AR visualization flow, user interactions, and learning scenarios; (b) the design of an information architecture based on clinical nursing taxonomy to facilitate material navigation and the integration between organ systems and nursing procedures; (c) the creation of wireframes and user interface prototypes referring to Google's Material Design guidelines to ensure visual consistency, usability, and responsive user experience on mobile devices; and (d) the development of evaluation instruments in the form of nursing clinical case-based questions designed to measure anatomical understanding, case analysis skills, and the application of physiological concepts in nursing practice. This phase also involved the selection of multimedia elements such as icons, colors, typography, 3D models, and AR interaction scenarios to ensure that the application would have an attractive appearance while supporting students' independent learning processes.

The Development phase was carried out using MyWebAR as the primary platform for developing Web-based Augmented Reality (WebAR) learning media. This platform was selected because it enables augmented reality experiences to be accessed directly through web browsers without requiring additional application installation, making it more practical, lightweight, and compatible with various devices and operating systems, including Android, iOS, and desktop platforms. The platform also provides image tracking features, interactive three-dimensional object integration, and real-time visualization support, which are well suited to the needs of anatomy learning in vocational nursing education. In the process of interface development and visual design, the researchers also utilized Canva to design the user interface, icons, material layouts, and supporting graphical elements to create a more attractive, communicative, and user-friendly application for students. The three-dimensional anatomical models used in the application were obtained from licensed sources and modified according to the needs of the Diploma III (D3) Nursing curriculum, including adjustments to organ structures, anatomical labeling, and the addition of clinical information relevant to nursing procedures. The developed application includes several main features, namely interactive AR visualization of human organ systems, a clinical explanation mode that connects anatomy with nursing procedures, interactive case-based quizzes, and a bookmark feature to support students' independent learning. The application was designed to be directly accessible through a web browser using links or QR codes, thereby facilitating distribution, implementation, and use during practicum activities without requiring additional installation processes, while also supporting flexible learning anytime and anywhere.

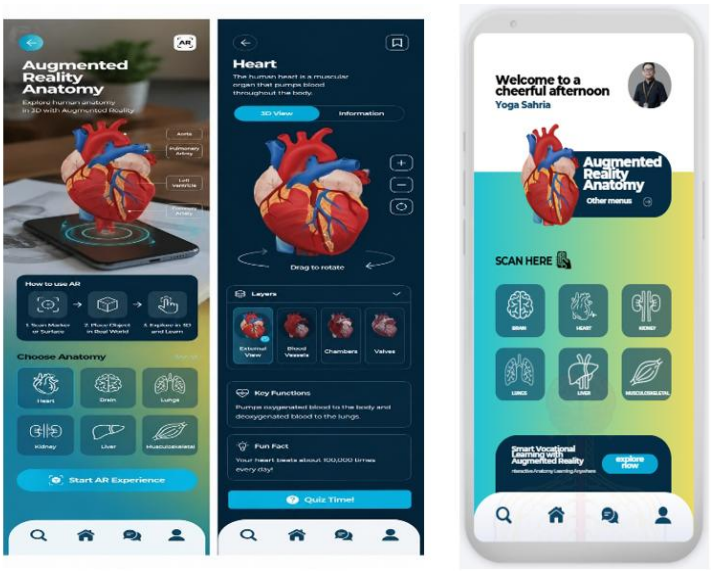

Figure 4. Anatomy AR Application Interface Prototype on Android Platform

The Implementation phase in this study was conducted through two cycles to ensure that the developed application could be optimally utilized by students. The first cycle consisted of a limited trial involving eight vocational students as initial respondents. At this stage, the evaluation focused on the application's functionality, ease of navigation, clarity of the user interface, and readability of the anatomical information presented. The trial results indicated several suggestions from users, particularly regarding menu navigation, which was considered less intuitive, as well as the size and contrast of organ labels, which were not sufficiently clear on certain devices. Based on these findings, revisions and improvements were made to enhance usability and provide a more comfortable learning experience for students. The second cycle was conducted as a full implementation involving all research participants, consisting of 40 students, over a period of six weeks with a frequency of two practicum sessions per week. During this stage, students used the AR application directly in anatomy learning and nursing practicum activities to measure the effectiveness of the application in improving anatomical understanding, practical skills, and overall user experience.

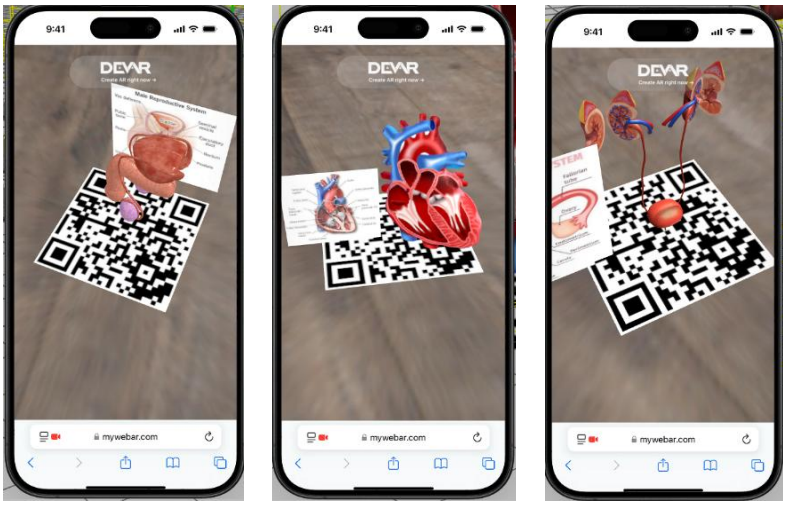

Figure 5. WebAR-Based Augmented Reality

D. Evaluation Instruments

The usability evaluation in this study was conducted using two standardized instruments that are widely applied in the evaluation of user experience in digital applications. The first instrument was the User Experience Questionnaire (UEQ), which has been previously validated [31]. The UEQ consists of 26 pairs of bipolar adjectives used to measure six main scales: Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation, and Novelty. Each UEQ item was rated on a scale ranging from −3 to +3, where positive values indicate a favorable user experience with the application. The second instrument was the System Usability Scale (SUS) [32], which consists of 10 statements rated on a 1–5 Likert scale and produces a final score ranging from 0 to 100 to measure the overall usability level of the application. In addition to usability evaluation, the effectiveness of the application was measured using pre-test and post-test instruments that had been validated by subject-matter experts, achieving a Content Validity Ratio (CVR) value of 0.83 and demonstrating high reliability with a Cronbach's Alpha value of 0.87. The improvement in learning outcomes was analyzed using the normalized gain (N-gain) calculation to determine the extent of students' improvement in understanding after using the application. All research data were analyzed using IBM SPSS Statistics with the application of the Wilcoxon Signed-Rank Test because the paired data obtained were not normally distributed, using a significance level of $p < 0.05$.

3. RESULTS AND DISCUSSION

A. Expert Validation Results

Product validation was conducted by five expert validators prior to the implementation stage to ensure the quality of the application in terms of content, media, and usability aspects. The validation process involved nursing subject-matter experts, learning media experts, and usability experts who had experience in the development of healthcare education technology. The material expert validation obtained an average score of 84.6%, categorized as "Highly Feasible," accompanied by several suggestions for improvement related to the enrichment of cardiovascular system content, the addition of clinical nursing terminology, and the refinement of organ function explanations to better align with the needs of vocational learning. The media expert validation achieved an average score of 82.3%, also categorized as "Highly Feasible," with recommendations for revisions regarding interface color contrast, consistency of visual design, and the typography size of organ labels to improve readability on mobile devices. Meanwhile, the usability expert validation obtained a score of 87.5%, categorized as "Highly Feasible," indicating that the application was considered easy to use, featured intuitive navigation, and was capable of providing a comfortable and interactive learning experience for users. In addition to

quantitative assessments, the validators also provided suggestions regarding the optimization of AR visualization performance, the loading speed of three-dimensional objects, and the simplification of menu access flows to improve the efficiency of application usage during practicum sessions. Based on the overall validation results, the application achieved an average validity score of 84.8% and was declared suitable for implementation in the anatomy learning process for vocational health students at STIKES Al Islam Yogyakarta.

B. User Experience Evaluation Results (UEQ)

The User Experience Questionnaire (UEQ) evaluation was conducted with 40 respondents after six weeks of application use to measure the quality of user experience toward the developed AR anatomy application. The evaluation results showed that all UEQ aspects obtained positive scores, ranging from 1.68 for the Efficiency aspect to 1.93 for the Novelty aspect, with an overall average score of 1.80. Based on the UEQ benchmark standards, scores above 0.8 are categorized as positive, scores above 1.5 are considered good, and scores approaching 2.0 are categorized as excellent. The Attractiveness aspect obtained an average score of 1.82, interpreted as excellent, indicating that the application was considered appealing and enjoyable to use. The Perspicuity aspect achieved a score of 1.75, suggesting that the application was easy for users to understand and learn. The Efficiency aspect obtained a score of 1.68 in the good category, demonstrating that users were able to use the application effectively and efficiently in supporting the learning process. Furthermore, the Dependability aspect achieved a score of 1.71, indicating that the application had good consistency and user control. The Stimulation aspect obtained a score of 1.89, signifying that the application was able to increase students' motivation and interest in learning anatomy. The Novelty aspect achieved the highest score of 1.93, categorized as excellent, indicating that the application was perceived as innovative and capable of providing a new learning experience for users. Overall, the UEQ evaluation results demonstrate that the AR anatomy application possesses a very good quality of user experience and is capable of providing an interactive, engaging, and supportive learning experience for anatomy education.

Table 2. UEQ Evaluation Results of the Anatomy AR Application (n=40)

Skala UEQ	Mean	Std. Dev	Variance	Interpretasi
Attractiveness	1.82	0.47	0.22	Excellent
Perspicuity	1.75	0.51	0.26	Excellent
Efficiency	1.68	0.53	0.28	Good
Dependability	1.71	0.49	0.24	Good
Stimulation	1.89	0.44	0.19	Excellent
Novelty	1.93	0.42	0.18	Excellent
Overall UX	**1.80**	**0.48**	**0.23**	**Excellent**

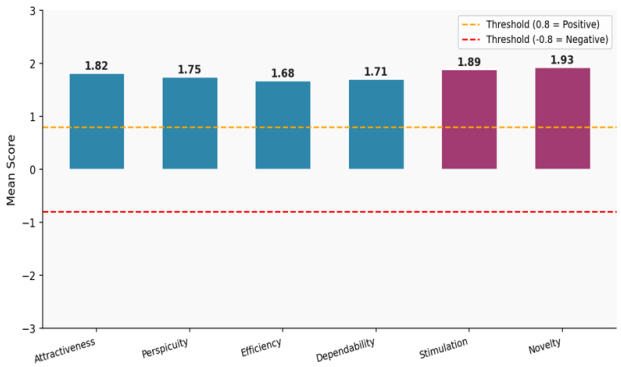

Figure 6. Six UEQ Scale Scores of the Anatomy AR Application

The Novelty scale obtained the highest score of 1.93, indicating that students experienced a new form of learning that they had never previously encountered in anatomy education. The high score in this dimension demonstrates that Augmented Reality (AR) technology is capable of providing a more innovative, interactive, and distinctive learning method compared to the conventional learning media commonly used. Students were not only able to observe static images of organs but could also directly interact with three-dimensional anatomical objects in real time, making the learning process more engaging and immersive. These findings are consistent with previous studies suggesting that novelty is often the most responsive dimension during first-time AR usage, particularly among users who are not yet familiar with immersive learning technologies. The Attractiveness scale, which achieved a high score of 1.82, indicates that the visual design of the application was considered capable of capturing users' attention and providing a positive impression throughout the learning process. The modern user interface, comfortable color combinations, realistic three-dimensional organ visualizations, and interactive navigation were identified as factors contributing to students' increased interest in using the application. These findings suggest that aesthetic quality and visual experience play important roles in enhancing students' learning motivation and engagement in technology-based learning environments.

The Efficiency scale obtained the relatively lowest score among all dimensions, with a value of 1.68, although it still fell within the Good category. Follow-up interview results revealed that some users experienced initial difficulties when using the application for the first time, particularly in understanding menu navigation and utilizing the bookmark feature. These challenges were mainly encountered by users who were not familiar with Augmented Reality (AR)-based interfaces, requiring an adaptation period to understand the application's interaction flow. Nevertheless, the majority of respondents stated that after several uses, the navigation process became easier and the application features could be utilized optimally. These findings are consistent with previous studies indicating that the efficiency aspect often receives lower scores in AR-based mobile applications with complex interactive features. This condition is generally associated with the learning curve during the early stages of use, where users need time to adapt to menu layouts, interaction mechanisms, and unfamiliar digital functions. Therefore, further improvements in interface design and navigation simplification are necessary to create a more intuitive, effective, and efficient user experience.

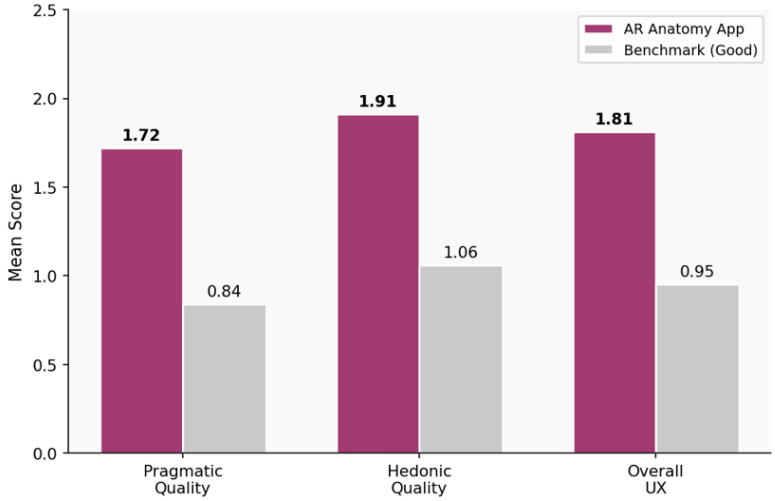

Figure 7. Comparison of UEQ Scores with International Benchmarks

Comparison with the international UEQ benchmark shows that the app's pragmatic quality (1.72) exceeds the good benchmark value (0.84), and its hedonic quality (1.91) also far exceeds the benchmark (1.06). This indicates that the developed anatomy AR app has a superior user experience quality compared to the average product in its category.

C. System Usability Scale (SUS) Evaluation Results

The System Usability Scale (SUS) evaluation yielded an average score of 81.3, which falls into the Excellent category with a Grade A rating based on its classification. These results indicate that the application has a very good level of usability and is positively received by users. Based on the score distribution in Table 3, 5th-semester students obtained a higher average score (83.4) than 3rd-semester students (79.8). This difference indicates that academic experience and familiarity with digital learning technology also influence the perceived ease of use of the application. The relatively low standard deviation values in each group indicate that respondents' assessments tend to be consistent and do not differ significantly between users. The high SUS score also indicates that the application interface is considered easy to understand, the features can be used effectively, and user interaction with the system runs well without the need for complex technical assistance. Thus, these evaluation results confirm that the application is suitable for use as an innovative Augmented Reality-based learning medium to support the understanding of anatomy and physiology for vocational health students.

Table 3. SUS Evaluation Results per Respondent Group

Respondent Group	Mean SUS	Std. Dev	Category
3th Semester Students (n=22)	79.8	6.4	Good (B)
5th Semester Students (n=18)	83.4	5.9	Excellent (A)
All Respondents (n=40)	**81.3**	**6.2**	**Excellent (A)**

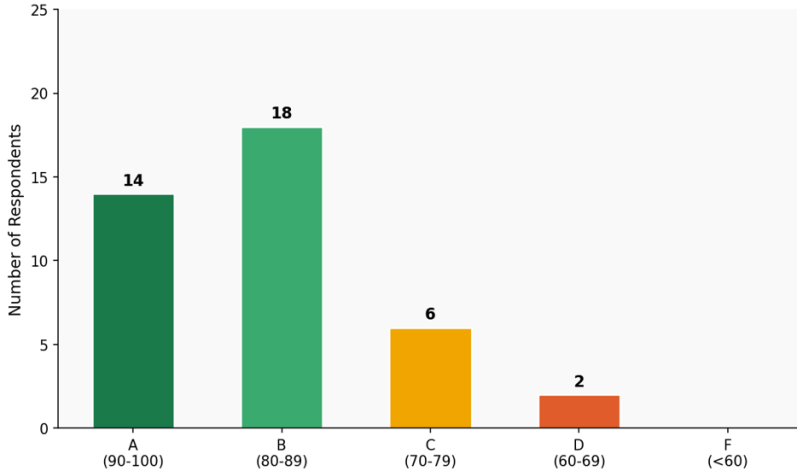

Figure 8. Distribution of SUS Score Categories for All Respondents (n=40)

Based on the Figure, the majority of respondents gave a very positive usability assessment of the application, with 32 out of 40 respondents obtaining SUS scores in the A (Excellent) and B (Good) categories, and no respondents gave a rating in the F (Poor) category. These findings indicate that the application has a high level of user acceptance and is able to provide a satisfactory user experience. Fifth-semester students obtained a higher average SUS score (83.4) than third-semester students (79.8), which is likely influenced by the level of familiarity of fifth-semester students with the use of mobile health applications and better digital learning technology. Upper-semester students tend to have more experience in utilizing interactive learning media and can therefore understand the application's navigation and features more quickly. However, the scores of third-semester students remained in the Good category, indicating that the application remains easy to use for new users without requiring intensive special training. These results show that the interface design, navigation, and integration of Augmented Reality (AR) features in the application have been designed to be intuitive enough to support the learning process effectively at various semester levels of vocational health students.

D. Learning Effectiveness: Pre-test and Post-test Analysis

The analysis of learning effectiveness was conducted by comparing pre-test and post-test scores on four main competency aspects, namely anatomical knowledge, organ identification skills, self-efficacy, and overall practicum scores. Based on the results, all aspects experienced a significant increase after using the AR Anatomu application in the learning process. The anatomical knowledge aspect increased from an average of 58.4 to 82.6 with an N-Gain value of 0.58, while organ identification skills increased from 55.2 to 81.3 with an N-Gain of 0.56. In the self-efficacy aspect, students' scores increased from 52.8 to 79.5 with an N-Gain of 0.57, indicating that the use of Augmented Reality (AR)-based learning media can increase students' confidence in understanding the structure and function of body organs. The overall practicum score also increased from 55.4 to 81.1 with an N-Gain of 0.57. All N-Gain values are in the moderate category, indicating that the application has a consistent positive impact on improving student competency. These results show that interactive 3D organ visualization and immersive learning experiences help students understand anatomical concepts more concretely, increase learning engagement, and strengthen practical skills in vocational health learning.

Table 4. Comparison of Pre-test and Post-test Values (n=40)

Assessment Aspects	Pre-test	Post-test	N-Gain	Category
Anatomical Knowledge	58.4	82.6	0.58	Medium
Organ Identification Skills	55.2	81.3	0.56	Medium
Self-efficacy	52.8	79.5	0.57	Medium
Overall Practicum Value	**55.4**	**81.1**	**0.57**	Medium

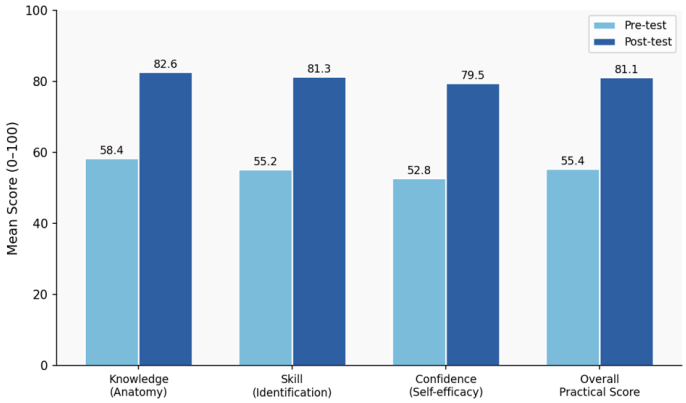

Figure 9. Comparison of Pre-test and Post-test Scores on Four Competency Aspects

The results of the Wilcoxon Signed-Rank Test revealed statistically significant differences between the pre-test and post-test scores across all assessed aspects ($p < 0.001$). The average N-gain score of 0.57 indicates an improvement within the moderate category ($0.3 < g < 0.7$) according to Hake's classification [16]. The highest improvement was observed in the anatomy knowledge aspect (N-gain = 0.58), while the lowest was found in organ identification skills (N-gain = 0.56), although the difference was not substantial. The moderate-category N-gain can be understood in the context that achieving high-category improvement ($g > 0.7$) is generally more difficult in complex nursing practical competencies compared to purely theoretical knowledge. Comparative studies in meta-analyses of AR in education have reported that the average effect size of AR in anatomy learning is $d = 0.67$, which is consistent with the findings of this study. A significant improvement was also observed in students' self-efficacy scores, increasing from 52.8 to 79.5. This finding is particularly important as it demonstrates a strong correlation between self-efficacy and the practical performance of healthcare students.

E. Integrative Discussion

Integratively, the findings of this study demonstrate that the developed AR anatomy application possesses advantages in three major dimensions: (1) excellent user experience quality based on the UEQ and SUS evaluations; (2) significant learning effectiveness in terms of knowledge, practical skills, and self-confidence; and (3) high accessibility, as indicated by the ease of use without requiring intensive training. However, this study also has several limitations: (1) the sample size was limited to a single institution, thereby restricting the generalizability of the findings; (2) the six-week evaluation period was insufficient to measure long-term retention; and (3) the absence of a true control group limited the ability to establish strong causal claims. Therefore, future studies are recommended to employ a quasi-experimental design involving control groups, larger samples from multiple institutions, and retention measurements conducted at 3- and 6-month intervals following the intervention.

4. CONCLUSION

This study successfully developed an Android-based anatomy Augmented Reality (AR) application using the ADDIE model aimed at D3 Nursing students at STIKES Al Islam Yogyakarta. Based on the results of a comprehensive evaluation, it can be concluded that: (1) The developed anatomy AR application has met expert validity standards with an average feasibility level of 84.8%; (2) The UEQ evaluation produced an overall score of 1.80 (Excellent category) which exceeds international benchmarks, with the highest score on the Novelty scale (1.93) and the lowest on the Efficiency scale (1.68); (3) The SUS evaluation produced an average score of 81.3 (Grade A/Excellent), indicating a very good level of usability; and (4) The application implementation was proven to significantly improve students' practical skills ($p<0.001$) with an average N-gain of 0.57 (moderate category). The findings of this study provide a significant contribution to the development of AR-based learning media in Indonesian vocational nursing education. The developed application is not only technically superior but also contextually relevant to the needs of the D3 Nursing curriculum. Future recommendations include expanding the full scope of organ system content, integrating with the institution's learning management system (LMS), and developing an iOS version to reach a wider audience.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia through the BIMA Research and Community Service funding program for supporting this research and development activity under Main Contract Number 284/C3/DT.05.00/PL-BARU/2026 and Derivative Contract Numbers 0350.21/LL5-INT/AL.04.03/2026 and 001/Kontrak/Lppm/Stikesalislamyk/V/2026. The authors also extend their appreciation to STIKES Al Islam Yogyakarta, all nursing lecturers, and students who participated in the needs analysis, testing, and evaluation process of the WebAR-based anatomy learning application, as well as all parties who contributed to the successful completion of this research and development project.

REFERENCES

[1] Syed Abd Halim, S. A., Yusoff, M. S. B., Yaman, M. N., Roslan, N. S., Tengku Muda, T. F. M., Ramli, R. R., & Hadie, S. N. H. (2024). The need to identify anatomy-related competencies in medical education. *Anatomical Sciences Education*, *17*(9), 1659-1667.

[2] Nubsaen, C., Visaetsilapanonta, P., Jiawiwatkul, U., & Chianchana, C. (2025). Soft skills development among vocational students in courses related to medical and comprehensive healthcare industry. *Kasetsart Journal of Social Sciences*, *46*(1), 460129-460129.

[3] Esmaeilzadeh, P. (2025). Ethical implications of using general-purpose LLMs in clinical settings: a comparative analysis of prompt engineering strategies and their impact on patient safety. *BMC Medical Informatics and Decision Making*, *25*(1), 342.

[4] Brenner, E., Pechriggl, E., & Konschake, M. (2025). The Human Cadaver as an Educational Tool: Classification and Comparison with Other Educational Tools. In *International Anatomical Education: The Trans-European Pedagogic Anatomy Research Group* (pp. 17-41). Cham: Springer Nature Switzerland.

[5] Zhang, Z., Gao, Y., Duan, H., & Hu, Y. (2025). Study on the Application of the Combination of Drawing and Multimedia in the Teaching of Human Anatomy. *Science Progress and Humanity*, *1*(1), 26-31.

[6] Sahria, Y., & Utami, E. N. (2026). Development of Augmented Reality-Based Anatomy Learning Media (ARANOMI) for Vocational Health Students. *MALCOM: Indonesian Journal of Machine Learning and Computer Science*, *6*(1), 62-72.

[7] Lee, J. W. Y., Low, L. X. T., Ong, D. W., Bello, F., & Soh, R. C. C. (2025). An activity theory approach to analysing student learning of human anatomy using a 3D-printed model and a digital resource. *BMC medical education*, *25*(1), 553.

[8] Manaroinsong, A. D., Domu, I., & Laamena, C. M. (2025). Design and Development of Construct 2-Based Learning Media for Teaching Three-Dimensional Geometry. *Kognitif: Jurnal Riset HOTS Pendidikan Matematika*, *5*(4), 1610-1622.

[9] Munguiko, C., Ngeno, A. C. K., Atukwatse, J., & Museene, S. K. (2025). Institutional Determinants of Academic Achievement in Biomedical Sciences: A Cross-Sectional Study of Nursing Students in Uganda. *Advances in Medical Education and Practice*, 2439-2462.

[10] Lampropoulos, G., Fernández-Arias, P., Del Bosque, A., & Vergara, D. (2025). Augmented reality in health education: Transforming nursing, healthcare, and medical education and training. *Nursing Reports*, *15*(8), 289.

[11] Muntian, L. (2025). Virtual and Augmented Reality in Healthcare Management Mechanisms for Maintaining Public Health: Literature Overview. *Ukrainian Journal of Medicine, Biology and Sports*, *10*(3), 36-50.

[12] Mondal, H., & Mondal, S. (2025). Adopting augmented reality and virtual reality in medical education in resource-limited settings: constraints and the way forward. *Advances in Physiology Education*, *49*(2), 503-507.

[13] Nguyen, H., Samsel, Z., Cormi, C., Acidi, B., Vibert, E., & Sandor, C. (2026, April). Studying the Implications of Augmented Reality for Teamwork in Open Liver Surgery. In *Proceedings of the 2026 CHI Conference on Human Factors in Computing Systems* (pp. 1-24).

[14] Geng, G., Green, K., Telford, A., & Zhu, Y. (2026). Engaging Young Minds: How Smart Augmented Reality Glasses Transform Learning Experiences in AR smart glasses Immersive Virtual Learning Environments (AR smart glasses IVLE). *Journal of Science Education and Technology*, 1-20.

[15] Chandra, S., & Boddu, H. S. H. (2026). Leveraging Augmented Reality for Precision and Productivity in Healthcare and Industrial Manufacturing: A Paradigm Shift in Innovation and Efficiency. In *Intersecting Public Administration and Technology for Public Trust and Citizen Engagement* (pp. 401-428). IGI Global Scientific Publishing.

[16] Elmalı, F., & Çıtak, H. (2026). Design, Development, and Formative Evaluation of a Tablet-Based Augmented Reality Application for Early Number Learning. *International Journal of Human–Computer Interaction*, 1-21.

[17] Penza, V., Neri, A., Koskinopoulou, M., Turco, E., Azam, M. A., & Mattos, L. S. (2026). Augmented Reality Navigation in Robot-Assisted Surgery. In *Handbook of Robotic and Image-Guided Surgery* (pp. 863-877). Elsevier.

[18] Mohamed, M., Yuriko, E., Kawagoe, Y., Kawamura, K., & Ikeuchi, M. (2026). AI-Based Augmented Reality Microscope for Real-Time Sperm Detection and Tracking in Micro-TESE. *Bioengineering*, *13*(1), 102.

[19] Wang, Y., & Ametefe, D. S. (2026). Immersive Technologies in Digital Museums: A Systematic Review of Virtual and Augmented Reality for Heritage Reconstruction and Visitor Experience. *PRESENCE: Virtual and Augmented Reality*, *35*, 71-93.

[20] Çevik, S. Ö., & Gök, B. (2026). Effects of Interactive Augmented Reality Application on Primary School Students' Misconceptions and Attitudes in Mathematics Education. *International Journal of Technology in Education*, *9*(1), 238-259.

[21] Shi, Y., & Yang, X. (2026). Virtual reality stimulating customer creativity in product co-development. *Humanities and Social Sciences Communications*, *13*(1), 156.

[22] Shehadeh, A., Alshboul, O., Abuaddous, M. A., Nimer, H. F., & Otoom, M. (2026). Emerging WEFE Technologies in Engineering Education: Integration of Optimization, Explainable AI, Digital Twins, and Virtual Reality. *Array*, 100756.

[23] Dechsling, A., Vister, O. M., Johansen, T. E., Børtveit, L., Herikstad, Y., & Nordahl-Hansen, A. (2026). Implementing virtual reality in special education: Teachers' perspectives. *International Journal of Disability, Development and Education*, *73*(2), 263-278.

[24] Lee, C., Saiki, H., Lin, T., Ikeda, E., Suzuki, K., Zhu-Tian, C., & Pfister, H. (2026, April). ViSTAR: Virtual Skill Training with Augmented Reality with 3D Avatars and LLM coaching agent. In *Proceedings of the 2026 CHI Conference on Human Factors in Computing Systems* (pp. 1-16).

[25] Almufarreh, A. (2026). Gamification in education and its impact on student academic performance: A conceptual model based on systematic literature review and PLS-SEM analysis. *Algorithms*, *19*(2), 143.

[26] Mondro, C. A., Benner, J. S., Thomson, B. J., & Lang, N. (2026). Implementation of an augmented reality sandbox as a topographic map learning tool in 100-level geology classes increases long-term knowledge retention and classroom engagement. *Journal of Geoscience Education*, *74*(1), 3-16.
[27] Abdelrahim, A. A. (2026). The impact of a critical fiction analysis based on using augmented reality technology on developing students' critical thinking and critical writing at Tabuk University. *Language teaching research*, *30*(4), 1814-1838.
[28] Sharma, B., Alhazmi, A., Nasir, N., & Bridget, B. (2026). Innovative Learning in Anatomy Education: Assessing the Impact of Low-Cost 3D Deep Learning Anatomical Models in Museum-Based Instruction. *Journal of Surgical Education*, *83*(1), 103748.
[29] Bolatli, G., Birisci, S., & Bolatli, Z. (2026). An Alternative Approach in Anatomy Education: Design of a Learning Environment Based on Artificial Intelligence-Supported Virtual Manipulatives and Investigation of Its Effectiveness. *Clinical Anatomy*, *39*(1), 30-44.
[30] Attallah, H. S., Abdelghani, R., & Hamed, O. (2025). Enhancing Radiation Oncology Delineation Skills Through Simulation-Based Learning (SBL): A Five-Step Practical Approach Using the ADDIE Model. *Journal of Cancer Education*, 1-6.
[31] Arifitama, B., & Syahputra, A. (2025, September). User Experience Analysis of a Mobile Augmented Reality Campus Visualization Using User Experience Questionnaire (UEQ) Approach. In *2025 International Seminar on Application for Technology of Information and Communication (iSemantic)* (pp. 275-280). IEEE.
[32] Hertzum, M. (2026). System Usability Scale: A Meta-Analysis of How SUS Relates to Workload, Task Time, and Error Rate. *International Journal of Human–Computer Interaction*, 1-14.