Evaluation of augmented reality applications as an interactive learning media for the female reproductive system.

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Devy Kurnia Ramadhani [a, 1*], Agus Sugiono [b, 2]

[a] Poltekkes Kemenkes Yogyakarta, Tata Bumi Street No.3, Banyuraden, Gamping, Sleman, DIY, Indonesia 55293
[b] Magelang, Jawa Tengah, Indonesia 56482
[1] devy.ramadhani@poltekkesjogja.ac.id*; [2] onowdev@gmail.com
*corresponding author

ABSTRACT

The use of augmented reality (AR) technology in health education is growing rapidly due to its ability to provide interactive and immersive learning experiences. However, research that comprehensively evaluates the feasibility of AR applications on female reproductive system material is still limited. This study aims to evaluate the feasibility of an augmented reality (AR)-based application as an interactive medium in learning about the female reproductive system. The evaluation was conducted on four main aspects, namely: software engineering, learning design, visual communication, and user acceptance. The research method used is a quantitative descriptive approach with data collection techniques through assessment questionnaires by experts and end users (students). The evaluation results show that the software engineering aspect obtained a feasibility score of 82% (excellent feasibility), the learning design aspect 85% (excellent feasibility), the visual communication aspect 71% (good feasibility), and the user acceptance aspect 85% (excellent feasibility). These findings indicate that the developed AR application is generally very suitable for use as a learning medium, especially in supporting the understanding of the concept of the female reproductive system interactively and contextually. However, the visual communication aspect still requires improvement to optimize the user experience. This research contributes to the development of innovative learning media in the field of health education and opens up opportunities for further research that tests the effectiveness of learning quantitatively and in the long term.

Keywords: **instructional design; educational technology; visual communication; software evaluation**

Introduction

The development of digital technology has driven a transformation in the world of education, particularly in the use of interactive media to improve learning effectiveness. One technology that is developing rapidly and is starting to be widely adopted in the education sector is Augmented Reality (AR).(1) AR enables the integration of virtual objects into the real world in real-time, thus enhancing the immersive, interactive, and visual learning experience.(2) In health education, particularly human anatomy and physiology, interactive visual media are essential to facilitate the understanding of complex concepts.(3) The use of extended reality (XR) technology, including AR, in anatomy education results in greater knowledge gains than traditional approaches, especially when used as a supplementary learning resource.(4)

Female reproductive system material is an important topic in health education, especially midwifery, but is often considered difficult to understand because it relies on textual explanations and static images in textbooks.(5)(6) Many students find it difficult to visualize the structure of organs and physiological processes that are dynamic and 3D.(7)(8) While several AR-based learning applications have been developed, few have specifically evaluated the effectiveness, quality, and quality of their interactivity and visual design in

supporting learning about the female reproductive system. Research by Putri and Pertiwi developed AR media for human reproductive system material and found it highly suitable for use in learning, with a 100% expert validation score and 83.5% student response.(9) A study by Villanueva et al. developed a mobile application using augmented reality for learning human anatomy. The study's findings revealed that 93.3% of participants agreed that the use of augmented reality was valuable for learning human anatomy, as it allows for interactive visualization of various parts of the human body. The study also showed that 28.3% of students scored "Excellent," while 68.3% scored "Predictable." Furthermore, 65% of students expressed interest in using augmented reality technology to learn anatomy.(10) Baran et al.'s research developed a reproductive system augmented reality application for sexual health classes. The results showed a significant increase from pre-test to post-test after using the AR application to enhance participants' knowledge of reproductive organs and their positions. Participants learned more about the female reproductive system than the male reproductive system.(11)

Much previous research has focused on AR application development, but few have assessed the integrated aspects of software engineering, visual communication quality, and instructional design within the context of female reproductive system instruction. There are no established standards for evaluating how AR supports students' cognitive understanding, learning experiences, and engagement in complex and visually sensitive material.(12)(13) As a result, it is difficult to assess whether existing AR applications are truly effective or merely technologically appealing but lacking pedagogical and visual strength.(8)(14) Although AR technology shows great potential in anatomy education, there are still limitations in research evaluating its effectiveness comprehensively.(15) A meta-analysis by Bogomolova et al. showed that there was no significant difference in anatomy test results between groups using AR and traditional teaching methods.(16) This suggests that further research is needed to understand how AR can be effectively integrated into anatomy learning, particularly the female reproductive system.(17)

This study aims to evaluate an AR application used in learning about the female reproductive system based on an approach that combines four main aspects: software engineering, instructional design, visual communication, and acceptance of the application. This study aims to determine the extent to which the AR application supports users' understanding, engagement, and overall learning experience on the topic of the female reproductive system.

Material and Method

This study used a descriptive quantitative approach. The research was conducted at the Clinical Laboratory of the Midwifery Department, Poltekkes Kemenkes Yogyakarta, Indonesia in 2021. The evaluation was based on four main aspects: software engineering, instructional design, visual communication, and acceptability. The subjects of this study were software experts (2 people), material experts (2 people), and 40 active students as application users. Inclusion criteria for software experts included a minimum of a bachelor's degree in a related field (Information Technology, Computer Science, Information Systems, or other software engineering fields); a minimum of 2 years of experience in developing mobile or augmented reality-based applications; involvement in at least one project or research related to the development of educational software or digital learning media; and willingness to provide objective assessment and input on the technical aspects of the application

(functionality, performance, interface, etc.). Meanwhile, exclusion criteria for software experts included not actively working in the field of software engineering in the past year; direct involvement in the development of the application being evaluated; and unwillingness to sign an agreement or research ethics document if required. Inclusion criteria for subject matter experts included having an academic background in Biology, Biology Education, Health, or Medicine, with a minimum of a Master's degree; having or currently teaching a course/topic on the female reproductive system at a university; having experience in developing curricula, teaching modules, or learning media related to the topic; and being willing to evaluate the suitability of the application content to academic standards and the curriculum. Exclusion criteria for subject matter experts included having no experience teaching or developing reproductive system material in the last 2 years; being directly involved in developing the content of the application being tested; being unwilling to follow the validation procedure or not completing the assessment instrument completely. Inclusion criteria for student respondents included being active students, currently taking courses in anatomy and physiology, the reproductive system, or related topics that discuss the female reproductive system, having never used a similar AR application for the reproductive system, and being willing to participate in the entire research process. Exclusion criteria for student respondents included students with limitations in accessing or operating digital devices; students who were not fully present in the learning process or failed to complete any of the testing stages; and students who provided incomplete data on the questionnaire. The research instruments consisted of observation sheets for testing software aspects and visual communication aspects by software experts, observation sheets for testing learning design aspects and visual communication aspects by material experts, and a questionnaire adapted from The Standardized Universal Percentile Rank Questionnaire (SUPR-Q) for student admissions. The data analysis technique used descriptive analysis, then the percentages were converted into predicate statements as in the following table:

Table 1. Statement Predicate Conversion

No	Percentage	Interpretation
1	0%-20%	Very poor feasibility
2	21%-40%	Poor feasibility
3	41%-60%	Moderate feasibility
4	61%-80%	Good feasibility
5	81%-100%	Excellent feasibility

Result and Discussion
Result

Testing of the software engineering aspects was conducted by two software experts. This testing was conducted to assess the software aspects using indicators of efficiency, reliability, maintainability, usability, functionality, portability, packaging, documentation, and reusability. Testing of the learning design aspects was conducted by two subject matter experts. This testing was conducted to assess the learning design aspects using indicators of learning objectives, relevance, materials, learning strategies, interactivity, learning motivation, contextuality and topicality, completeness and quality of learning aids, clarity and ease of understanding, systematicity, consistency of evaluation with learning objectives, accuracy and precision of evaluation tools, and feedback. Meanwhile, testing of the visual

communication aspects was conducted by two software experts and two subject matter experts. This testing was conducted to assess the visual communication aspects using indicators of communicativeness, creativity, simplicity, audio, visuals, moving media, and interactive layout.

The results of the study on the evaluation of an augmented reality (AR) application as an interactive learning medium for the female reproductive system indicated significant value in supporting improved learning comprehension. Data analysis was conducted using descriptive quantitative methods, where the assessment scores were converted into predicate categories: 0–20% = Very poor feasibility; 21–40% = Poor feasibility; 41–60% = Moderate feasibility; 61–80% = Good feasibility; and 81–100% = Excellent feasibility.

Table 2. Test Results of Software Engineering, Learning Design, and Visual Communication Aspects by Experts

Aspect	No	Indicator	Sub Indicator	Software Expert Assessment		Material Expert Assessment		Percentage
				1	2	1	2	
Software engineering	1	Efficiency	Responsiveness to assigned actions/tasks	5	4			82%
	2	Reliability	Error tolerance	4	4			
	3	Maintainability	Analytical ability	5	5			
	4	Usability	Easy to operate, understand, learn, and operate, attractive	5	4			
	5	Functionality	Suitability, Accuracy, System Interaction, Security	4	4			
	6	Portability	Adaptability	5	5			
	7	Packaging	Program Packaging	4	4			
	8	Documentation	Installation instructions	3	3			
			Troubleshooting instructions	3	3			
	9	Reusability	Reusability to develop other learning media	4	4			
Instructional Design	1	Learning objectives	The learning objectives to be achieved are clearly outlined.			5	4	85%
	2	Relevance	Alignment with learning objectives.			5	5	
	3	Material	Coverage of material.			4	4	
			Depth of material.			4	3	

Aspect	No	Indicator	Sub Indicator	Software Expert Assessment		Material Expert Assessment		Percentage
				1	**2**	**1**	**2**	
	4	Learning strategies	Appropriate use of learning strategies			4	4	
	5	Interactivity	Interactive media, two-way communication.			4	4	
	6	Learning motivation	Providing learning motivation.			4	4	
	7	Contextualization and actualization	Contextualization and actualization.			4	4	
	8	Completeness and quality of learning aids	Completeness and quality of learning aids.			4	4	
	9	Clarity and ease of understanding	Clarity and ease of understanding of descriptions.			3	4	
	10	Systematics	Systematic, coherent, and clear logical flow			4	4	
	11	Consistency of evaluation with learning objectives, accuracy, and appropriateness of evaluation tools	Evaluation instrument content aligns with learning objectives. Evaluation instruments used are appropriate.			3	4	
	12	Feedback	Feedback on evaluation results is provided.			3	3	
Visual Communication	1	Communicative	Consistent with the message and acceptable/aligned with the target audience's wishes	4	4	4	4	71%
	2	Creativity	Creative in ideas and how to express them	4	4	4	4	
	3	Simple	Not complex	4	4	2	2	
	4	Audio	Narrative, sound effects, background music	3	3	3	3	
	5	Visual	Layout design, typography, colour	3	3	3	3	
	6	Moving Media	Animation, movies	4	4	4	4	
	7	Interactive Layout	Navigation icons	4	4	4	4	

Based on the evaluation results, the software engineering aspect scored 82%, a rating of "excellent feasibility." This indicates that the AR application has stable technical performance, adequate functionality, and a high level of reliability, providing an efficient and uninterrupted learning experience. High feasibility in this aspect directly contributes to the continuity of the learning process, as students can use the application easily without encountering errors or technical glitches. The instructional design aspect scored the highest, at 85%, a rating of "excellent feasibility." This finding confirms that the AR application successfully integrates instructional design principles, content appropriateness, and interactivity, fostering understanding of female reproductive system concepts. This score also indicates that the media serves not only as a visual aid but also as a tool capable of facilitating active and meaningful learning. Meanwhile, the visual communication aspect scored 71%, a rating of "good feasibility." While still in the "good feasibility" category, this score indicates that visual aspects, such as graphic quality, colour composition, and design aesthetics, are not yet optimal in supporting learning engagement. Differences in user aesthetic perceptions likely influence these results, providing room for improvement to make the learning experience more engaging and immersive.

Application acceptance testing was conducted with 40 university students as users. The following are the results of the acceptance testing:

Table 3. Results of User Acceptance Testing

No	Statement	Percentage
1	The initial display of the main menu is attractive.	89%
2	The layout of the buttons, text, images, and animations is organized, making it easier for me to learn.	84%
3	The background design is attractive, with appropriate colour composition so it doesn't interfere with reading the text or images.	88%
4	The font size and spacing are appropriate, making it clearly legible.	90%
5	The buttons are easy to recognize and easy to operate.	98%
6	The colour combination in the media is appropriate.	88%
7	The images are clear and support the learning material.	90%
8	The animations are interesting and help me understand the material.	83%
9	The videos are clear and support the learning material.	84%
10	The sound effects make the learning environment more engaging and less boring.	78%
11	I feel interested and motivated when learning using this learning media.	88%
12	I understand the learning objectives of this media.	78%
13	The instructions for use in the media are clear and helpful.	89%
14	The language used is communicative, making it easy for me to understand the message.	88%
15	The material presented is interesting and easy to understand.	86%
16	The structure of the material is coherent.	85%
17	The discussion in the practice questions is easy to understand, strengthening my understanding.	79%
18	The instructions for answering the test questions are clear and understandable.	79%
19	The feedback helps me understand the material.	75%

No	Statement	Percentage
20	By learning using this media, I have gained a better understanding of the female reproductive system.	85%
	Average	**85%**

The user acceptance test obtained a score of 85%, indicating an excellent feasibility rating. This score reflects that users found the application easy to use, relevant to their learning needs, and suitable for adoption in formal learning. The high level of acceptance also confirms that students are positively motivated to use the application as an interactive medium.

Overall, the study results indicate that the three main aspects of software engineering, instructional design, and user acceptance are in the excellent feasibility category, while the visual communication aspect is in the good feasibility category. This indicates that the developed AR application has had a significant impact on improving learning comprehension by providing a stable, relevant, and well-received interactive learning experience for users. However, optimization of the visual design is still needed to maximize the effectiveness of the medium.

Discussion

This study evaluated an augmented reality (AR) application as an interactive learning medium for the female reproductive system by examining four main aspects: software engineering, instructional design, visual communication, and user acceptance. The evaluation results indicated that the software engineering aspect received a excellent feasibility rating (82%), reflecting the application's good stability, functionality, and technical efficiency. The instructional design aspect was also rated excellent feasibility (85%), indicating the content's suitability to the learning objectives and the successful delivery of the material interactively. The visual communication aspect received a good feasibility rating (71%), indicating that the interface design and visual elements still have room for improvement. The user acceptance aspect received an excellent feasibility rating (85%), indicating that users were satisfied, easily understood the material, and were willing to use the application in their learning. Overall, this application can be categorized as very good as an AR-based interactive learning medium, particularly for the female reproductive system.

These research results align with previous findings demonstrating the effectiveness of AR media in enhancing understanding of biological concepts. For example, research by Putri and Pertiwi (2023) showed that AR media on human reproductive system material received 100% validation from material experts and 95% validation from media experts, as well as 83.5% student responses, all of which were in the very good category.(9) In addition, a meta-analysis by García-Robles et al. (2024) showed that the use of AR in anatomy education can improve spatial understanding and accelerate the learning process..(4) A study by Salimi et al. (2024) found that AR did not significantly improve knowledge scores compared to traditional methods, highlighting the importance of appropriate instructional design and technology integration.(15) However, this study is novel in that it simultaneously integrates the evaluation of four key aspects: software engineering, instructional design, visual communication, and user acceptance, a practice not widely explored in previous studies. Furthermore, the specific focus on the female reproductive system provides a unique contribution to the development of AR-based learning media in health education.

The main advantage of this study lies in the use of a quantitative evaluative approach with eligibility criteria that allows for objective measurement of all four aspects studied: software engineering, instructional design, visual communication, and user acceptance. This approach is relatively rare when applied simultaneously in the context of AR learning focused on female reproductive material. Often, previous studies only measure a few aspects, such as user acceptance or overall learning effectiveness, without examining the technical elements (software), instructional design, and visual aspects in detail. For example, a study by Rao et al. (2025) evaluated the role of AR in improving medical students' anatomical understanding and clinical thinking using a self-report survey after AR learning.(18) However, that study did not explicitly distinguish between the technical aspects of the software, instructional design, and visual communication with objective feasibility criteria, as was done in this study.

Furthermore, the participation of end-users, namely healthcare students, adds to the external validity of this study. Because healthcare students are direct users of the female reproductive system material, their perceptions and acceptance are highly relevant to the application's use in a real-life educational context. This aligns with the findings of Uymaz and Uymaz's (2022) study, which used nursing students as a sample and found a high level of intention to use AR as a means of self-directed learning.(19) By involving a population closely connected to the material, your research strengthens the relevance and generalizability of the results in the context of health education. The combination of objective measures of technical and design aspects, along with a well-targeted sample, makes this research more comprehensive than more one-sided studies. Furthermore, the use of an instrument that converts scores into clear predicates (e.g., "feasible," "very feasible") provides clarity of interpretation and ease of drawing practical conclusions that are sometimes lacking in similar studies.

This advantage not only strengthens the claim that the developed AR application has high technical and pedagogical reliability but also allows for more specific recommendations for improving the visual aspects, as visual communication lags behind other aspects. For example, a review study conducted by Graser & Böhm (2024) found that many studies focused on user acceptance and technology variables, but few objectively measured software quality and instructional design as part of an integrated evaluation.(20)

However, this study has several limitations. The self-developed evaluation instrument, although validated, still has the potential to introduce subjective bias from assessors. Furthermore, the relatively small and homogeneous sample size may limit the generalizability of the study results. The visual communication aspect, which only received a "decent" score, also indicates the need for improvements in the interface design and visual elements of the application.

The high scores for the learning design and user acceptance aspects indicate that interactivity and ease of use play a significant role in the AR-based learning experience. The highly acceptable software engineering aspect indicates that the development method used successfully ensured the stability and functionality of the system. However, the visual communication aspect needs improvement, possibly by involving professional designers to enhance the aesthetics and visual comfort of the application. This study did not directly test the long-term learning effectiveness or improvements in learning outcomes after using the application. Furthermore, cross-device accessibility or affordability for users with special needs were not tested. The visual aspect still requires further exploration, including possible collaboration with professional designers.

Conclusion

This study shows that the augmented reality (AR) application developed as an interactive learning medium for the female reproductive system received excellent feasibility evaluation result in the software engineering (82%), learning design (85%), and user acceptance (85%). This confirms that the application has met the technical and pedagogical feasibility standards, as well as user satisfaction, as an innovative learning medium. Meanwhile, the visual communication aspect received a good feasibility (71%), indicating room for improvement in the quality of the graphic design, illustrations, and visual representations used in the application. These findings confirm that the use of AR has significant potential to support learning about female anatomy and the reproductive system, with advantages in interactivity, ease of access, and user acceptance. However, this study is still limited to the feasibility testing stage, and therefore cannot fully describe the application's long-term effectiveness in improving student learning outcomes.

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