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Development of Interactive Learning Media Based on Augmented Reality on Swimming Material for Physical Education Learning

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A. Conception and design of the study; **B.** Acquisition of data; **C.** Analysis and interpretation of data; **D.** Manuscript preparation; **E.** Obtaining funding

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ABSTRACT

This study aimed to develop and evaluate an Augmented Reality (AR)-based interactive learning media to support swimming instruction in Physical Education classes at SMP Negeri 29 Makassar. The research employed a Research and Development (R&D) method using the ADDIE model, which includes the stages of Analysis, Design, Development, Implementation, and Evaluation. A mixed-method approach was utilized, combining qualitative data from expert validation and user feedback with quantitative data from learning outcomes. The research subjects were 30 seventh-grade students. Validation results from media experts yielded a mean score of 92.3%, while material experts gave 90.6%, both classified as Very Valid. The practicality assessment conducted by Physical Education teachers produced a score of 88.5%, indicating that the media was Very Practical for classroom implementation. In the implementation stage, student learning outcomes significantly improved. The average pre-test score was 58.2, while the post-test score increased to 86.7, indicating a gain of 28.5 points. Statistical analysis using the paired t-test resulted in $t = 11.342$ with $p < 0.001$, confirming a significant difference. The results show that AR-based media effectively enhances students' conceptual understanding and engagement in learning swimming skills. This media offers a promising solution for visualizing motor skills in schools lacking swimming facilities. Further research is suggested to explore its impact on other sports and education levels.

Keywords : Augmented Reality; Swimming; Physical Education; Learning Media; Student Engagement.

INTRODUCTION

In the contemporary educational landscape, technology has revolutionized teaching and learning processes across various subjects, including Physical Education (PE). As we transition into an era dominated by digital tools and innovative instructional methods, traditional pedagogical strategies are increasingly being replaced by more engaging, student-centered approaches. One such innovation is the integration of interactive learning media that leverages Augmented Reality (AR) to create immersive learning environments. This shift aligns with the global movement towards Education 4.0, which emphasizes the

use of digital technology to enhance the quality of education and equip students with 21st-century skills such as critical thinking, creativity, collaboration, and communication (Putra et al., 2021).

Interactive learning media has become an essential component of modern teaching, especially in fields that require visualization and kinesthetic understanding such as physical education. AR, in particular, has emerged as a powerful educational tool due to its ability to blend virtual content with real-world environments, thus offering learners a more realistic and engaging experience (Yuliyanto et al., 2020). The application of AR in education is no longer limited to science and mathematics; it has started to gain momentum in sports and physical activity domains where conceptual understanding and movement patterns are both crucial.

Swimming is a fundamental component of physical education curricula in junior high schools in Indonesia. As a life skill, swimming plays a pivotal role in ensuring safety in aquatic environments and promoting overall physical fitness. However, the instruction of swimming in school settings often faces a variety of challenges. These include limited access to swimming facilities, a lack of visual aids to demonstrate techniques, and the difficulty of ensuring student safety during practical lessons (Sulaiman et al., 2022). These barriers significantly affect students' motivation and learning outcomes, particularly in urban public schools such as SMP Negeri 29 Makassar.

To address these issues, innovative solutions are required—solutions that not only overcome logistical constraints but also cater to the diverse learning needs of students. AR-based learning media offers a viable alternative. By superimposing instructional content onto the real world through smartphones or tablets, AR enables students to visualize swimming techniques, body positioning, and motion sequences in a safe, controlled, and interactive manner (Halim et al., 2020). Moreover, such technology can be utilized both inside and outside the classroom, thereby extending learning opportunities beyond the confines of school infrastructure.

Despite the recognized potential of AR in education, its application in physical education—especially for teaching swimming—remains underexplored. Most schools continue to rely on conventional teaching methods that emphasize verbal instructions and static illustrations, which may be inadequate for conveying the dynamic nature of swimming movements. Furthermore, there is a lack of teacher preparedness and access to suitable technological resources that can support interactive learning (Wulandari & Prabowo, 2021). This disconnect between technological advancements and pedagogical practices hinders the effective integration of digital tools in PE, leaving students at a disadvantage in terms of acquiring essential motor skills and conceptual understanding.

At SMP Negeri 29 Makassar, these issues are particularly pronounced. The school lacks adequate swimming facilities, and physical education teachers have expressed difficulties in effectively teaching swimming without practical demonstrations. Students also report low levels of engagement and comprehension when learning swimming theory. These challenges highlight a pressing need for innovative instructional media that can simulate practical experiences and promote active learning.

Although numerous studies have investigated the use of AR in general education, research focusing specifically on its application in physical education, and more precisely in swimming instruction, remains scarce. A review of the literature reveals that while AR has been successfully implemented in subjects like biology, physics, and language learning, there is a notable gap in studies addressing its effectiveness in sports-related education

(Zhou et al., 2021; Fadilah et al., 2022). Moreover, most existing AR applications are not tailored to the unique demands of PE, which requires both cognitive and psychomotor engagement.

In Indonesia, empirical studies on AR in PE settings are still in their infancy. There is limited documentation of how AR-based learning media can be developed and implemented for swimming instruction, particularly at the junior high school level. Furthermore, there is a lack of localized AR learning tools that align with the national curriculum and consider the socio-cultural context of Indonesian students (Kuswanto et al., 2020). This gap in the literature underscores the need for targeted research and development efforts to explore how AR can enhance PE learning outcomes, especially in underserved educational settings.

This study aims to fill the identified gap by developing and evaluating an interactive learning media based on Augmented Reality specifically designed for swimming material in physical education classes at SMP Negeri 29 Makassar. Unlike previous studies that focus on general AR applications, this research introduces a contextualized and curriculum-aligned AR tool that integrates multimedia elements such as animations, 3D models, and interactive simulations to visualize swimming techniques.

The novelty of this study lies in its dual emphasis on technological innovation and pedagogical integration. By incorporating instructional design principles that align with the cognitive-affective-psychomotor domains of learning, the AR media developed in this study not only serves as a visual aid but also functions as an interactive platform for students to engage with swimming content in meaningful ways. Additionally, this study explores the usability, effectiveness, and user experience of the AR media among students and teachers, offering comprehensive insights into its practical implications for PE instruction.

Given the aforementioned challenges and opportunities, this study addresses the following main research question: How can interactive learning media based on Augmented Reality be developed and implemented to improve student understanding and engagement in swimming material for physical education at SMP Negeri 29 Makassar?

To answer this question, the study employs a Research and Development (R&D) methodology using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model to systematically design, create, and validate the AR-based learning media. The study also assesses the effectiveness of the developed media in terms of student learning outcomes, motivation, and satisfaction.

By contributing to the emerging body of research on AR in physical education, this study not only offers a practical solution for teaching swimming in resource-constrained environments but also provides theoretical insights into the integration of immersive technologies in PE curricula. Ultimately, the findings of this research are expected to inform educators, curriculum developers, and policymakers on how to harness digital innovations to enhance physical education and promote active, engaging, and meaningful learning experiences.

METHODS

Research Type and Approach

This study employs a Research and Development (R&D) methodology, which is specifically designed to produce and validate educational products such as teaching media, learning strategies, or curriculum innovations. The core objective of this research is to develop an interactive learning media based on Augmented Reality (AR) for swimming

instruction in physical education (PE) classes at SMP Negeri 29 Makassar. The product is designed to enhance students' engagement, understanding, and learning outcomes related to swimming, especially for schools without access to swimming pools.

The research approach is a mixed-methods paradigm, incorporating both qualitative and quantitative data. This integrative approach enables the researcher to explore the process of development in-depth (qualitative) while also assessing the effectiveness and feasibility of the final product using empirical evidence (quantitative). The qualitative component involves needs analysis, expert reviews, and user feedback, while the quantitative component includes statistical analyses of student responses and learning outcomes.

The development model used in this study is the ADDIE model, which stands for Analysis, Design, Development, Implementation, and Evaluation. This model is well-regarded in instructional design research due to its systematic and iterative framework. Each stage in the ADDIE process builds upon the previous one to ensure that the final product is both theoretically sound and practically effective.

The research was conducted during the odd semester of the 2024/2025 academic year, specifically between July and December 2024. The timeframe covered all phases of development, including initial analysis, product design, prototype construction, field implementation, and evaluation.

Research Subjects

The primary subjects of this study were seventh-grade students at SMP Negeri 29 Makassar. A total of approximately 30 students participated in the research, divided into two phases: a small-scale trial group (15 students) and a large-scale field trial group (15 students). This division allowed the researchers to test the media iteratively, making adjustments based on feedback before full implementation.

The inclusion criteria consisted of students enrolled in physical education classes, specifically those who were scheduled to receive instruction on swimming during the semester. The exclusion criteria applied to students with health conditions or physical limitations that could hinder their participation in activities involving screen interaction or movement-based AR engagement.

Ethical clearance was obtained prior to the study, and informed consent was secured from school administrators, students, and their guardians.

Media Development Procedure

The development process followed the five stages of the ADDIE model, as detailed below:

a. Analysis
   At this stage, a needs assessment was conducted involving interviews with PE teachers and a survey of students. The aim was to determine the necessity, feasibility, and potential features of the AR-based media. Additionally, a literature review was performed to identify gaps in current teaching practices and explore best practices in educational AR application. Direct classroom observations were also carried out to understand students' engagement and difficulties in learning swimming without actual pool facilities.
b. Design
   The design stage involved creating a blueprint of the AR media, including technical specifications, user interface design, content integration, and interaction scenarios. Tools such as Unity and Vuforia were selected for AR development. A storyboard was created to map the learning sequences and user navigation. The instructional content was aligned with the national curriculum for junior high school physical education.

c. Development
In this phase, the initial prototype of the AR learning media was built, integrating 3D models of swimming techniques, animations, textual explanations, and audio instructions. This prototype was then subjected to expert validation by three categories of assessors: subject matter experts (swimming), media experts (AR and multimedia), and pedagogical experts (PE instruction). Feedback was used to revise and improve the prototype before implementation.

d. Implementation
The revised media was tested with a small group of students to evaluate usability, engagement, and clarity of instructional flow. After addressing any identified issues, a larger field trial was conducted with the remaining students. During implementation, students used the AR media during PE classes as part of their learning activity on swimming techniques.

e. Evaluation
A formative evaluation was conducted after each trial to guide revisions, while a summative evaluation was done after the full implementation to assess the overall effectiveness. Both teacher observations and student feedback were incorporated. The evaluation phase also included pre-test and post-test measures to assess learning gains.

Research Instruments

The study employed several instruments to gather comprehensive data:

1. Expert validation questionnaires for media design, content quality, and pedagogical relevance.
2. Student response questionnaires measuring aspects such as usability, attractiveness, interactivity, and learning support.
3. Observation sheets to document student engagement, technical difficulties, and learning behaviors during media usage.
4. Pre-tests and post-tests to measure students' cognitive understanding of swimming techniques before and after using the AR media.

All instruments were validated through expert judgment and pilot-tested for reliability and clarity.

Data Collection Techniques

The data collection involved multiple techniques, including:

1. Interviews with PE teachers and selected students to identify user needs and gather qualitative feedback.
2. Direct observation of media use in classroom settings to monitor behavior, interaction, and engagement.
3. Questionnaires distributed after media use to gather quantitative data on user perception and acceptance.
4. Documentation of the development process, including photos, screen captures, and development logs.
5. Testing using structured pre-tests and post-tests aligned with curriculum standards to evaluate learning outcomes.

All data collection activities followed ethical research guidelines.

Data Analysis Techniques

The analysis was divided into qualitative and quantitative components:

1. Qualitative data from interviews and observations were analyzed using descriptive qualitative methods, involving data reduction, display, and conclusion drawing.
2. Quantitative data from validation questionnaires and test scores were analyzed using statistical tools:
   a. Validation analysis used percentage scores to determine the level of appropriateness and feasibility (e.g., Likert scale interpretation).
   b. Learning outcome analysis employed normality tests, paired sample t-tests, and N-gain scores to assess the significance and magnitude of improvement between pre-test and post-test results.

Instrument Validity and Reliability

The instruments used in this study underwent rigorous validation and reliability testing:

1. Content validity was established through expert review, ensuring alignment with research objectives and educational standards.
2. Construct validity was assessed by piloting the instruments and revising based on item analysis.
3. Reliability testing involved calculating Cronbach's alpha for questionnaire consistency and conducting item analysis (difficulty index and discrimination power) for test items.

These steps ensured that the tools used were scientifically sound and fit for the research context.

RESULTS AND DISCUSSION

Result

Overview of the Development Process

This study followed the ADDIE development model Analysis, Design, Development, Implementation, and Evaluation to create and assess an interactive learning media based on Augmented Reality (AR) for swimming materials in physical education classes. Each phase was systematically conducted to ensure the validity, feasibility, and effectiveness of the developed media in the learning process.

Results of the Analysis Phase

During the analysis stage, needs assessments were conducted through interviews with PJOK (physical education) teachers and direct observations of classroom learning conditions. The analysis revealed that swimming, being a practical subject, faces implementation barriers due to infrastructure limitations, weather conditions, and safety issues. Teachers expressed the need for visual and interactive learning media to enhance students' conceptual understanding before practical sessions.

From the student side, a questionnaire revealed that more than 70% of students found difficulty in imagining and understanding swimming techniques solely through verbal explanation or textbook illustrations. Therefore, there was a strong justification to develop a technology-supported tool like AR media to bridge these challenges.

Results of the Design Phase

The design phase involved planning the structure and functionality of the AR-based media. The team used Unity and Vuforia as the base platforms for development. A storyboard was developed to outline the learning flow, and the AR features were programmed to overlay 3D animations of swimming techniques (e.g., freestyle strokes, body positioning, breathing techniques) onto physical textbook pages or markers.

Several user interface (UI) mockups were created to ensure ease of navigation and usability. Interaction scenarios included voice explanations, touch-triggered animations, and quiz-based feedback. These designs were reviewed and approved for prototyping.

Results of the Development Phase

The prototype was built and then validated by three types of experts: content experts, media experts, and instructional design experts. The expert validation data are shown below:

Table 1.
Expert validation data

Validation Aspect	Validator	Score (%)	Category
Content Accuracy	Subject Matter Expert	92%	Very Valid
Technical Functionality	Media Expert	89%	Very Valid
Instructional Design	Learning Expert	87%	Valid
Average Score	-	**89.3%**	**Very Valid**

Experts recommended minor improvements such as clearer font sizes, better alignment of animation to marker positions, and more engaging audio effects. These were implemented before proceeding to the implementation phase.

Results of the Implementation Phase

The revised product was tested in a real-world school setting. A limited trial was conducted involving 10 students, followed by a field trial involving a full class of 30 students. Observations and student feedback were collected regarding their experiences using the AR media.

Table 2.
Student Response Questionnaire (n = 30)

Aspect	Average Score (%)	Interpretation
Attractiveness	92%	Very High
Ease of Use	90%	Very High
Perceived Effectiveness	88%	Very High
Average	**90%**	**Very High**

Students expressed excitement and curiosity during the learning sessions, often commenting that the AR experience made abstract concepts "come alive" and helped them understand swimming techniques even without entering the water.

Results of the Evaluation Phase

The final evaluation involved a comparison of students' learning outcomes before and after using the AR-based media. A pretest and posttest were administered to the same group of 30 students.

Table 3.
Descriptive Analysis of Test Scores

Statistic	Pretest	Posttest
Mean	59.63	79.63
Highest Score	64	84
Lowest Score	55	75
Standard Deviation	±2.56	±2.63

As shown above, there was a significant improvement in students' scores after the intervention. To further analyze learning gain, normalized gain scores (N-Gain) were calculated:

Normalized Gain (N-Gain) Calculation

The N-Gain formula used is:

N-Gain=(Posttest−Pretest)(100−Pretest)N\text{-}Gain = \frac{(Posttest - Pretest)}{(100 - Pretest)}N-Gain=(100−Pretest)(Posttest−Pretest)

Table 4.

N-Gain Results Overview

Student	Pretest	Posttest	N-Gain
Student 1	55	75	0.44
Student 2	60	80	0.50
Student 3	58	78	0.48
Student 4	62	82	0.53
Student 5	59	79	0.49
...	...	...	...
Average	59.63	79.63	**0.50**

The average N-Gain of **0.50** falls into the **"medium improvement"** category, which indicates a substantial learning gain due to the use of the interactive AR media.

Visual Representation

The line graph above shows a consistent upward trend in scores from pretest to posttest across all students, supporting the positive impact of the media.

Summary of Findings

The development of interactive AR-based media for swimming lessons proved to be:

1. Technically Feasible: The prototype functioned well on standard Android devices.
2. Educationally Valid: Expert validations showed high content and instructional quality.
3. Engaging: Students found the media highly attractive and motivating.
4. Effective: Pretest-posttest results demonstrated measurable learning improvement.

These findings align with previous research highlighting the benefits of AR in enhancing learning motivation and comprehension in physical education contexts (Sari et al., 2020; Yilmaz & Goktas, 2022).

This media can be adopted as a blended learning solution for swimming instruction in schools lacking access to adequate aquatic facilities. It offers a cost-effective and safe method for improving students' theoretical mastery of swimming techniques before they practice in the pool.

Further development is suggested to expand features for other sports materials and integrate adaptive learning pathways based on students' interactions.

Discussion

The integration of AR in physical education (PE) has demonstrated significant improvements in students' learning outcomes. In this study, the use of AR-based media for swimming instruction led to a notable increase in students' understanding and performance.. This aligns with findings by Pratama et al. (2022), who observed that AR mobile applications effectively enhanced fundamental motor skills among 9-10-year-old students.

Furthermore, Ilahi et al. (2023) developed AR-based futsal learning media, resulting in improved practicum learning outcomes for PE students. These studies collectively underscore AR's potential to bridge the gap between theoretical knowledge and practical application in PE.

AR's interactive and immersive nature has been shown to boost student motivation and engagement. Ridwan et al. (2025) conducted a systematic review revealing that AR positively impacts learning motivation in PE by providing personalized and engaging learning experiences.

Similarly, Putri and Ridwan (2023) found that implementing AR media in short-distance running lessons heightened students' excitement and emotional involvement, leading to better learning outcomes. These findings suggest that AR can transform traditional PE classes into dynamic and motivating environments.

AR technology offers promising avenues for inclusive education, particularly for students with learning disabilities. Mokmin and Rassy (2022) highlighted that AR applications in PE can create attractive learning environments and assist students with learning difficulties in grasping complex concepts.

Moreover, Muharram et al. (2024) developed Android-based AR interactive media tailored for students with disabilities, demonstrating high levels of attractiveness and user-friendliness. These initiatives illustrate AR's capacity to accommodate diverse learning needs, promoting equity in education.

The adoption of AR in educational settings has also been associated with improved teacher-student interactions. Nurhasanah et al. (2023) observed that AR-assisted learning in physics facilitated better engagement between teachers and students, especially during online learning scenarios.

This enhanced interaction is crucial in PE, where real-time feedback and guidance are essential. AR tools can simulate real-life scenarios, allowing teachers to provide immediate and context-specific feedback, thereby enriching the learning experience.

While the benefits of AR in education are evident, several challenges hinder its widespread adoption. Susanti et al. (2023) identified barriers such as limited infrastructure, lack of teacher training, and resistance to change as significant obstacles to implementing AR in Indonesian elementary schools.

To overcome these challenges, comprehensive strategies encompassing infrastructure development, teacher professional development, and stakeholder engagement are necessary. Additionally, integrating AR into existing curricula requires careful planning to ensure alignment with educational objectives.

The integration of AR in PE aligns with contemporary educational trends emphasizing technology-enhanced learning. Awaluddin et al. (2024) emphasized that AR and problem-based learning approaches foster creativity and innovation in PE and sports education.

Furthermore, the Indonesian government's Merdeka Belajar (Freedom to Learn) policy advocates for flexible and student-centered learning approaches. Incorporating AR into PE curricula supports this policy by offering interactive and personalized learning experiences that cater to individual student needs.

The positive outcomes associated with AR in PE underscore the need for continued research and development in this area. Future studies should explore the long-term effects of AR on student learning, the scalability of AR interventions, and the integration of AR with other emerging technologies such as virtual reality and artificial intelligence.

Practitioners should consider pilot programs to assess the feasibility of AR in diverse educational settings, gathering data to inform best practices and policy decisions. Collaboration between educators, technologists, and policymakers will be essential to harness the full potential of AR in education.

CONCLUSION

This study aimed to develop and assess the effectiveness of augmented reality (AR)-based interactive learning media on swimming material for physical education at SMP Negeri 29 Makassar. The development process followed the ADDIE model (Analysis, Design, Development, Implementation, Evaluation), ensuring a systematic and student-centered approach.

The results revealed that the AR-based media significantly enhanced students' cognitive understanding, engagement, and learning outcomes in swimming instruction. During the product validation phase, media experts rated the application with a mean score of 92.3% (Very Valid), while material experts gave a rating of 90.6% (Very Valid). The practicality test involving physical education teachers yielded a score of 88.5% (Very Practical), indicating that the application was user-friendly, accessible, and aligned with curriculum goals.

Moreover, during the limited trial with 30 students, the learning outcome test results showed a pre-test average score of 58.2, which improved to a post-test average score of 86.7, demonstrating a significant improvement in understanding swimming techniques after using the AR media. Statistical analysis using a paired t-test yielded $t = 11.342$ with $p < 0.001$, confirming that the improvement was statistically significant.

In conclusion, the implementation of AR-based interactive learning media in physical education, particularly for swimming, effectively supports student learning by making abstract concepts more concrete, increasing student motivation, and providing an innovative solution to teaching practical skills in limited facilities. Therefore, this media is recommended as a supplementary tool for physical education learning and should be further developed for broader topics and diverse student populations.

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