

Flashcard Augmented Reality as an Interactive Solution in Swimming Learning in the Digital Era

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ABSTRACT

Swimming is an essential life skill that promotes physical fitness, safety, and confidence, especially for elementary school students. However, learning swimming techniques in schools is often constrained by limited facilities, lack of instructional time, and the abstract nature of swimming concepts when presented theoretically. To address these challenges, this study explores the use of Augmented Reality (AR) flashcards as an innovative and interactive learning tool to improve students' understanding of basic swimming concepts. This research adopts a quasi-experimental design involving 25 students from Muhammadiyah Alam Surya Mentari Elementary School in Surakarta. The AR flashcards were developed to visualize swimming techniques in 3D animation, allowing students to engage with the material interactively through mobile devices. Pre-test and post-test assessments were conducted to measure the effectiveness of the media. In terms of score range, the minimum score improved from 40 in the pre-test to 70 in the post-test, while the maximum score increased from 75 to 100. This indicates not only a general improvement across all participants but also that the lowest-performing students made considerable progress. These findings strongly support the effectiveness of the learning intervention in enhancing swimming skills among elementary students. The results show a significant improvement in students' conceptual understanding of swimming after using the AR flashcards. This suggests that AR-based flashcards can serve as an effective educational solution, especially in contexts where practical swimming sessions are limited. The integration of AR technology into physical education can enhance engagement, motivation, and comprehension among young learners in the digital era.

KEYWORDS: *augmented_reality, elementary_education, flashcards, interactive_media, swimming_learning,*

INTRODUCTION

Swimming is not only a form of physical activity but also a crucial life skill that every child should acquire from an early age (Rihatno *et al.*, 2018; Vedernikova *et al.*, 2021; Jariono *et al.*, 2022). In the context of elementary physical education, swimming plays a vital role in developing motor skills, water safety awareness, and overall physical literacy (Sakti Rumpoko *et al.*, 2022, 2023). Despite its importance, many schools—especially in developing countries—face challenges in providing effective swimming instruction. These challenges often include the lack of accessible swimming facilities, insufficient time for practice, and the difficulty students experience in understanding swimming techniques through conventional, theory-based teaching methods. In the midst of these challenges, the development of digital technology actually offers a great opportunity to enrich the way we teach and learn. One technology that is now beginning to gain attention in the world of education is Augmented Reality (AR) (Eisenhardt *et al.*, 2023; Feri Apriani, Rahma Devi and Nurkadri, 2023; Rahayu *et al.*, 2024). This technology allows virtual objects to be displayed in a real environment interactively, enabling students to see, hear, and even experience learning in a more vivid way. In the context of swimming, this could certainly be a promising breakthrough. One form of the implementation of this technology is Augmented Reality-based flashcards (Crosby, 2017; Kine

and Education, 2018; Binti *et al.*, 2019; Vedernikova *et al.*, 2021; Ganchar *et al.*, 2022; Feri Apriani, Rahma Devi and Nurkadri, 2023; Alkasasbeh *et al.*, 2024; Rahayu *et al.*, 2024). This media presents a visualization of swimming techniques in the form of three-dimensional animations, complete with interactive explanations. Students not only read or look at static images, but they can also witness a simulation of swimming movements directly from their devices. This approach combines visual, verbal, and kinesthetic aspects—which is very helpful in building conceptual understanding before they actually get into the water. Unfortunately, the use of innovative media like this is still not widely adopted in swimming lessons, especially at the elementary school level. Many teachers still rely on conventional methods that are less relevant to the characteristics of today's digital generation. This creates a gap between the potential of technology and the reality of learning that occurs in the classroom and in the field. One promising application of AR in education is through the development of flashcards equipped with 3D animations and multimedia elements. These AR flashcards allow students to visualize swimming movements, body positions, and technique explanations in a more tangible and engaging way, especially before entering the pool for physical practice. This approach addresses the learning gap between theory and practice by bringing abstract concepts to life. Starting from this condition, this article aims to offer a solution: Augmented Reality-based flashcards as an interactive medium that not only attracts students' attention but also enhances their understanding of swimming concepts more comprehensively. By integrating this media into the learning process, it is hoped that students can gain a more enjoyable, effective, and relevant learning experience in line with the demands of the times. However, the implementation of AR in physical education—particularly in swimming instruction at the elementary level—remains limited. Therefore, this study aims to investigate the effectiveness of Augmented Reality flashcards as an interactive learning medium to enhance students' conceptual understanding of swimming. The study is conducted at Muhammadiyah Alam Surya Mentari Elementary School in Surakarta with a quasi-experimental design involving 25 students.

METHODOLOGY

Research Design : This study employed a quasi-experimental design with a one-group pre-test and post-test model. A total of 25 elementary school students from Muhammadiyah Alam Surya Mentari in Surakarta were selected as research participants. The study aimed to assess the impact of Augmented Reality flashcards on students' understanding of swimming techniques. The learning intervention involved the use of AR flashcards displaying 3D models and animations of swimming movements. These flashcards could be accessed via mobile devices or tablets, allowing students to engage interactively with the visualized swimming content. Before the intervention, students were given a pre-test to evaluate their initial understanding of basic swimming concepts. Following a series of learning sessions using the AR flashcards, a post-test was conducted to measure conceptual improvement. Data analysis was performed using descriptive and inferential statistics to determine the significance of the learning gains observed.

Population and sample used. The population of this study consisted of fourth-grade students from Muhammadiyah Alam Surya Mentari Elementary School in Surakarta, Indonesia. The school was selected purposively due to its openness to educational technology implementation and its structured physical education curriculum. A total of 25 students (13 boys and 12 girls), aged between 9 and 10 years, were selected as the sample using purposive sampling. These students had previously received basic swimming instruction but showed varying levels of conceptual understanding, making them ideal participants for evaluating the effectiveness of the AR flashcard intervention. No control group was included, as the study adopted a one-group pre-test-post-test design to measure learning improvement within the same group.

Data Collection Techniques. Data were collected using a combination of quantitative and qualitative approaches to ensure a comprehensive understanding of the effectiveness of the intervention.

Pre-test and Post-test: Used to quantitatively assess students' understanding of swimming concepts before and after the use of AR flashcards.

Observation: Conducted during the learning sessions to monitor students' engagement, reactions, and interaction with the AR media.

Student Feedback Questionnaire: A short, structured questionnaire was distributed at the end of the intervention to gather students' perceptions regarding the usefulness, attractiveness, and ease of use of the AR flashcards.

Tools or Instruments Used. AR Flashcards: The main instructional tool was a set of Augmented Reality flashcards, designed and developed specifically for this study. Each flashcard displayed 3D animations of swimming movements (floating, arm stroke, breathing techniques) when scanned with a mobile application. Swimming Concept Test: A 10-item multiple-choice test was developed by researchers and validated by physical education experts. The questions focused on understanding body position, breathing, arm and leg movements, and safety rules in swimming. Observation Sheet: Used by the researcher during the learning process to record students' behaviors, engagement levels, and their interaction with the flashcards. Feedback Questionnaire: A Likert-scale questionnaire (1–5) to assess user experience aspects, including media appeal, ease of use, perceived learning support, and overall satisfaction.

Data Analysis Methods. Descriptive Statistics: Pre-test and post-test scores were analyzed to calculate mean, median, and standard deviation. These descriptive data illustrated general trends in learning improvement. Inferential Statistics: A paired sample t-test was performed using SPSS software to determine whether there was a statistically significant difference between the pre-test and post-test results. Qualitative Analysis: Observational notes and open-ended responses from the questionnaire were analyzed using content analysis, focusing on themes such as engagement, motivation, and user experience with the AR flashcards.

RESULTS AND DISCUSSION

The results of this study indicate a significant improvement in students' conceptual understanding of swimming after the implementation of Augmented Reality (AR) flashcards. The average pre-test score was 56.4, while the post-test score increased to 84.8, with a mean gain of 28.4 points. A paired sample t-test showed a statistically significant difference between the pre- and post-test results ($p < 0.001$). Additionally, qualitative data from student feedback revealed high levels of engagement and satisfaction. More than 88% of students reported that the AR flashcards made the learning process more interesting and easier to understand.

These findings highlight the effectiveness of AR flashcards as a tool to support conceptual learning in swimming education. By transforming static information into dynamic 3D models, students were able to visualize and internalize abstract swimming techniques, such as breathing rhythm, body posture, and arm-leg coordination, prior to physical practice. This is particularly significant in elementary school contexts, where abstract thinking is still developing and students benefit greatly from concrete visual aids. The use of AR also aligns with students' digital literacy and learning preferences in the 21st century.

The improvement in test scores confirms the hypothesis that AR media can enhance conceptual understanding. These results align with previous studies, such as:

- Ibáñez & Delgado-Kloos (2018), who found that AR improves engagement and learning retention in physical education.
- Wu et al. (2013), who argued that AR helps bridge the gap between theoretical content and real-world application.

Given that students in this study showed both improved outcomes and reported higher motivation, the findings meet expectations and demonstrate consistency with existing literature on the effectiveness of AR-based learning tools. The findings are consistent with studies such as: Chang et al. (2014), who reported increased learning performance in science classes through AR visualization. Putra et al. (2022), who developed AR-based tools for sport motor learning and found similar increases in comprehension and engagement. However, this study is among the first in Indonesia to apply AR in the context of swimming education, especially at the elementary school level, thereby contributing a unique perspective to the growing body of AR research in physical education.

While AR flashcards likely played a central role in improving students' understanding, other factors may have contributed, such as:

- The novelty effect of using new technology, which may temporarily increase motivation and attention.
- The structured and guided learning sessions, which might not reflect typical classroom dynamics.

- Possible peer collaboration and discussion that enhanced learning beyond the AR content itself.

These alternative factors, although not the main focus, should be considered when interpreting the results.

The success of AR flashcards in this study suggests that educational institutions should consider integrating AR into physical education curricula, especially in contexts with limited access to practical swimming facilities. It also emphasizes the need for teacher training in digital pedagogy and instructional design to fully utilize the potential of AR tools.

Moreover, the study showcases how low-cost, mobile-based AR applications can bridge the gap between theory and practice, especially in skill-based subjects such as swimming.

Several limitations must be acknowledged:

- The small sample size (n=25) and single-site implementation limit the generalizability of the findings.
- The short intervention period may not reflect long-term retention of knowledge or skills.
- The study focused only on cognitive outcomes (concept understanding), not on actual swimming performance or psychomotor skill transfer.
- No control group was used to compare the effectiveness of AR against traditional methods alone.

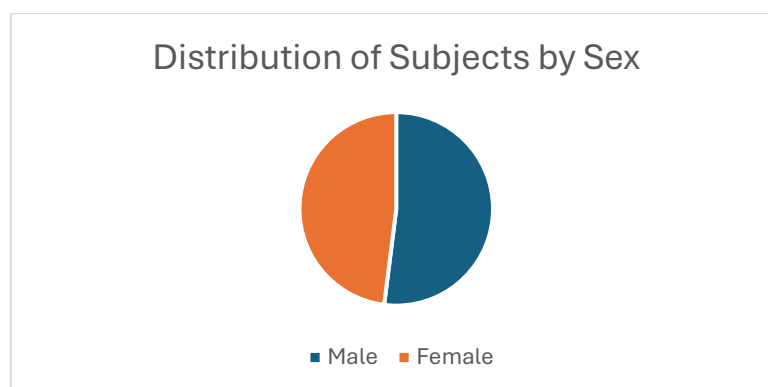
Future research could address the following directions: Expand the sample size and include multiple schools from different regions to increase external validity. Conduct longitudinal studies to observe the impact of AR flashcards on long-term knowledge retention and actual swimming skills. Include control groups and other types of digital interventions (e.g., videos, VR) for comparative analysis. Explore teacher perspectives and implementation challenges, as teacher readiness plays a crucial role in technology adoption.

Figure and Table

Table 1
Subjects by Sex

No.	Sex	Number	Percentage
1	Female	12	48
2	Male	13	52
Total		25	100

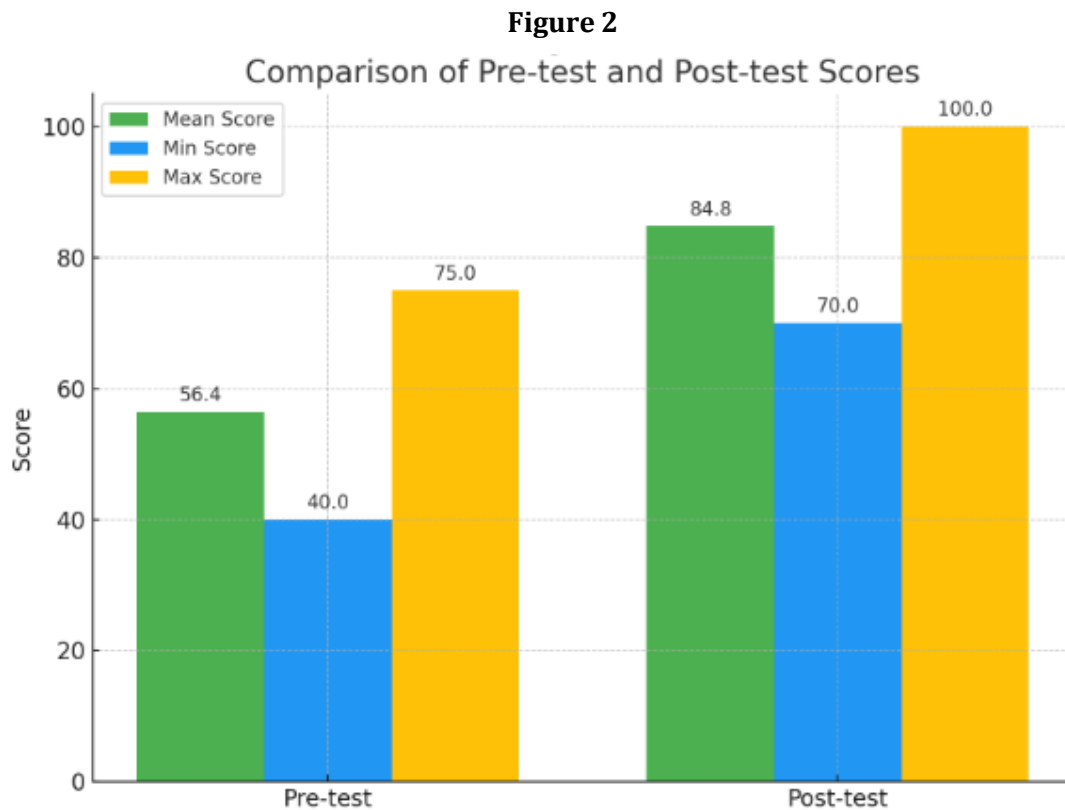
Figure 1



Note. The chart shows that 52% of the participants were male and 48% were female, indicating a nearly balanced gender distribution among the 25 total respondents

Table 2
Comparison of Pre-Test and Post-test scores

	Mean Score	Standard Deviation	Minimum Score	Maximum Score
Pre-test	56.4	10.8	40	75
Post-test	84.8	8.9	70	100



Note :The graph highlights the improvement in students' performance after the AR flashcard intervention, with a substantial increase in both mean and minimum scores from pre- to post-test.

CONCLUSION

This study demonstrates that the integration of Augmented Reality (AR) flashcards into swimming instruction significantly improves elementary students' conceptual understanding of swimming techniques. The increase in average scores from 56.4 on the pre-test to 84.8 on the post-test (see Table 1 and Figure 1) indicates a strong positive impact of the intervention. Additionally, student feedback supports the idea that AR media not only enhances comprehension but also increases engagement and motivation in learning.

The findings align with existing literature that emphasizes the benefits of AR in making abstract content more concrete, particularly in physical education contexts where practice is limited. The interactive and visual nature of AR technology bridges the gap between theoretical instruction and practical execution, making it an effective tool for foundational learning in swimming.

Although the study was conducted on a limited scale, it provides promising evidence that AR-based flashcards are a viable and innovative educational resource, especially for schools with limited swimming facilities or practice time.

Recommendation

Based on the findings of this study, the following recommendations are proposed:

1. **Wider Implementation:** Schools should consider adopting AR flashcards as a complementary tool in swimming instruction, particularly at the elementary level where visualization aids are highly beneficial.
2. **Teacher Training:** Professional development programs should be organized to train physical education teachers in the integration of AR tools into their lesson plans, ensuring effective and purposeful use of the technology.
3. **Curriculum Integration:** Education authorities may explore the inclusion of AR-based learning media in the national or local curriculum, especially in subjects where conceptual learning precedes practical application.
4. **Further Research:** Future studies should involve larger and more diverse samples, include control groups, and measure long-term retention and psychomotor skill transfer to fully understand the scope of AR's impact in physical education.
5. **Multimodal Expansion:** Developers and educators can expand AR flashcards to include audio instructions, interactive quizzes, or gamified challenges, making the experience more immersive and adaptive to various learning styles.

By embracing digital innovation such as AR, education—especially in skill-based domains like swimming—can evolve to meet the needs of today's learners, making learning more effective, inclusive, and future-oriented.

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