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Breaststroke Swimming Learning Model Based on Virtual Reality: A Quasi-Experimental Study on College Students

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Abstract

This study aims to assess the effectiveness of a virtual reality-based breaststroke learning model on improving students' swimming skills. The background of this study is based on the limitations of conventional learning methods in visualizing swimming technique movements in detail, resulting in low understanding of movement and quality of students' motor skills. The study used a quasi-experimental design with a pretest-posttest control group pattern. The research subjects consisted of physical education students who were divided into an experimental group (using virtual reality media) and a control group (using conventional learning). The research instrument was a breaststroke swimming skills test that covered aspects of body position, arm movement, leg movement, breathing, and motor coordination. Data were analyzed using statistical tests to compare the improvement in learning outcomes of the two groups. The results showed that the group that participated in virtual reality-based learning experienced a significantly higher improvement in breaststroke swimming skills compared to the conventional learning group. These findings indicate that the integration of virtual reality technology in swimming learning can improve movement understanding, the quality of technique execution, and student learning motivation. Thus, a virtual reality-based learning model is recommended as an innovative alternative in swimming learning in higher education.

Keywords: Virtual Reality, Swimming Learning, Breaststroke, Quasi-Experiment, Motor Skills

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A. Introduction

Advances in science and technology in the digital era have driven transformations in various sectors, including physical education and sports. The integration of technology into the learning process is no longer merely complementary but has evolved into a strategic tool for improving the quality of learning, the effectiveness of material delivery, and student engagement. In the context of physical education in higher education, learning sports skills requires an approach that focuses not only on physical training but also on understanding movement concepts, visualizing techniques, and mastering motor skills gradually (Culajara, 2022; Em et al., 2026; Ferraz et al., 2024a).

Learning swimming, particularly breaststroke, is complex because it involves simultaneous coordination of arm and leg movements, breathing, and body position (Ginting et al., 2021; Raswin & Nasution, 2025). In practice, swimming instruction in universities is still dominated by direct demonstration methods and repetitive pool practice. While these methods are effective in building motor skills, they face several limitations, such as limited training time, a less-than-ideal faculty-student ratio, and students' difficulty accurately observing technical details from certain angles. Furthermore, psychological factors such as aquaphobia and pool anxiety can also hinder the learning process, especially for beginners (Ferraz et al., 2024b; Østerlie et al., 2025; Trisnawati et al., 2024).

Virtual Reality (VR) offers the potential to be an innovative learning medium capable of delivering immersive and interactive learning experiences. Through three-dimensional visual simulations, students can observe breaststroke swimming techniques from various perspectives, slow down or repeat movements, and systematically study movement sequences before practicing directly in the water (Abdul Halim, 2023; Erviana & Sepriansyah, 2024; Gazali et al.,2026). This approach aligns with motor learning principles that emphasize the importance of mental representation of movement (motor imagery) and cognitive understanding of skills before physical implementation. With VR, students have the opportunity to build a deeper conceptual understanding of swimming techniques, thus hopefully making the transfer process to real-world motor skills more effective (Amprasi et al., 2022; Belajaya et al., 2023; Bujang et al., 2025; Fernando & Wira Yudha Kusuma, 2018; Iqbal et al., 2025a, 2025b; Suprayitno et al., 2023; Sutyo Nugraha et al., 2023; Witte et al., 2025).

Several studies related to previous research have shown that the use of VR-based training systems can improve motor learning and response speed (Sudiadharma, 2026). VR provides an immersive and interactive learning experience in Physical Education, as well as increasing student engagement in sports learning (Achmad Maulana, 2025). Alexander et al., (2025) VR media has been proven effective in improving sports motor skills. Several of these studies explain the importance of developing VR and the research gap in the article explaining the urgency that researchers put forward.

The urgency of implementing VR in swimming instruction is increasingly relevant to the demands of 21st-century learning, which emphasizes the use of digital technology, experiential learning, and increased student motivation and independence in learning. VR media has the potential to increase student interest and engagement because it provides a more engaging learning experience than conventional methods. Furthermore, VR can function as a safety learning medium, particularly in the early stages of swimming instruction, as students can learn basic techniques without being directly exposed to risks in the aquatic environment. This is crucial in the context

of swimming instruction in universities which often have limited facilities and practice time.

Based on this description, an empirical study is needed to test the effectiveness of a virtual reality-based breaststroke learning model in improving students' swimming skills compared to conventional learning. Quasi-experimental research is a relevant approach to obtain scientific evidence regarding the contribution of VR to improving the quality of swimming learning. The research results are expected to provide a theoretical and practical basis for physical education lecturers and higher education institutions in integrating virtual reality technology as part of innovative sports skills learning.

B. Methods

This study uses a descriptive design. quasi-experiment with a pattern non-equivalent control group pretest– posttest. This design was chosen because the researcher could not perform fullsubject randomization (random assi gnment), but instead used existing classes/groups (Sugiyono, 2023). The experimental group was given treatment in the form of Breaststroke swimming learning model based on Virtual Reality (VR), while the control group was given breaststroke swimming lessons using conventional methods

This study used a quasi-experimental design with a non-equivalent pretest–posttest control group. Both groups were given a pretest to measure their initial breaststroke swimming skills. Next, the experimental group received treatment in the form of virtual reality (VR)-based learning, while the control group received conventional learning. After all treatments were completed, both groups were given a posttest to measure their breaststroke swimming skill improvement. Table 1 explains the research design.

Table 1. Quasi-Experimental Research Design (Pretest-Posttest Non-Equivalent Control Group)

Group	Pretest (O1)	Treatment (X)	Posttest (O2)	Treatment Description
Experimental Group	O1	X	O2	Breaststroke swimming learning model based on Virtual Reality (VR): 3D visualization
Control Group	O1	–	O2	Conventional learning: lecturer demonstration, hands-on practice in the pool, and verbal feedback

Symbol Description

1. O_1= Pretest of breaststroke swimming skills
2. O_2= Posttest of breaststroke swimming skills
3. X= Treatment (Virtual Reality-based learning model)
4. –= Without special treatment (conventional method)

The research was conducted in several meetings (6–8 meetings).

1. Experimental group: Students receive VR-based breaststroke training before practicing in the pool. The VR material displays three- dimensional visualizations of body position, arm and leg movements, breathing, and coordination. Students can observe the movements from various angles, perform visual repetitions, and understand the sequence of techniques before practicing them in the water.
2. Control group: Students take part in conventional breaststroke swimming lessons through lecture

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explanations, live demonstrations in the pool, and repeated practice.

After all treatments were completed, both groups were given a posttest with the same instrument as the pretest. The main research instrument is a breaststroke swimming skills test based on a performance assessment rubric which can be seen in Table 2 as follows.

Table 2. Breaststroke Swimming Skills Assessment Instrument (Performance Rubric)

Rated Aspect	1 (Very Poor)	2 (Less)	3 (Enough)	4 (Good)	5 (Very Good)
Body Position	Body often sinks; not parallel to water; head too raised/submerged	Body position unstable; hips drop; poor balance	Body fairly aligned; occasional imbalance	Body stable and parallel; streamlined; minimal resistance	Body very stable; optimal streamlined position; excellent balance
Arm Movement	Movements not in accordance with technique; not symmetrical; push-pull phase unclear	Movements out of sync; partially incorrect patterns	Movement pattern fairly correct; thrust not maximal	Correct and symmetrical movement; effective thrust	Very precise, strong, smooth, and efficient arm movement
Foot Movement	Kick not forming frog motion; incorrect direction; weak push	Footwork not compact; irregular movement	Footwork fairly correct; moderate push	Correct footwork; strong and stable thrust	Very efficient footwork; maximum push; excellent propulsion
Breathing	Irregular breathing; frequent breath holding; exhalation not coordinated	Breathing pattern not synchronized with movement	Breathing fairly synchronized; sometimes late	Breathing in sync with movement; good rhythm	Breathing highly controlled; perfectly synchronized with movement
Overall Movement	Uncoordinated movements; stiff; frequent stopping	Low coordination; transitions not smooth	Adequate coordination; some transitions less smooth	Good coordination; smooth transitions between movements	Excellent coordination; fluid, rhythmic, and efficient movements

Data Analysis Techniques

Data analysis was carried out quantitatively with the following stages:

1. Analysis prerequisite tests, including normality tests and variance homogeneity tests to ensure that the data meets the parametric test assumptions.
2. The test of improvement in groups (paired sample t-test) was used to determine the differences in pretest and posttest scores in each group.
3. Independent sample t-test to compare the improvement in learning outcomes between the experimental group and the control group.
4. Calculation of effect size (e.g. Cohen's d) to determine the extent of the influence of using VR media on improving breaststroke swimming skills.

The significance level used was $\alpha = 0.05$. The results of the analysis are presented in the form of average values, standard deviations, significance values, and interpretations of the practical meaning of the research findings.

C. Result and Discussion

Result

The results showed an increase in breaststroke swimming skills in both groups after receiving the learning treatment. Based on descriptive analysis, the average pretest scores in the experimental and control groups were in a relatively equal initial ability category. After the treatment, the average posttest scores for both groups increased, but the increase in the experimental group using the Virtual Reality (VR)-based learning model was higher than that of the control group using conventional learning.

Inferentially, the results of the paired sample t-test showed a significant difference between the pretest and posttest scores in the experimental group ($p < 0.05$). This indicates that the implementation of VR-based learning effectively improved students' breaststroke swimming skills. A significant increase was also found in the control group ($p < 0.05$), indicating that conventional learning still has a positive impact on learning outcomes. However, the magnitude of the increase in the control group was lower than that in the experimental group.

The results of the independent sample t-test showed that the breaststroke swimming skill score gain in the experimental group was significantly higher than in the control group ($p < 0.05$). This finding is supported by the large effect size value, indicating that the use of Virtual Reality media has a strong practical influence on improving students' breaststroke swimming skills.

When examined by assessment aspect, the most significant improvement in the experimental group occurred in overall motor coordination and arm movements, followed by breathing, body position, and leg movements. Three-dimensional visualization of techniques through VR helped students understand the sequence of movements, rhythm, and synchronization between arms, legs, and breathing before practicing in the pool. Meanwhile, the control group showed more moderate improvement and tended to vary between individuals, particularly in motor coordination.

Overall, the results of this study indicate that the integration of Virtual Reality in breaststroke swimming learning can significantly improve the quality of the learning process and student motor skill learning outcomes compared to conventional learning methods. Descriptive pretest and posttest results for breaststroke swimming skills can be seen in Table 3 below.

Table 3. Descriptive pretest and posttest of power stroke swimming skills

Group	N	Pretest (Mean ± SD)	Posttest (Mean ± SD)	N-Gain (Δ Mean)
Experimental (VR)	25	56.40 ± 6.85	56.40 ± 6.85	56.40 ± 6.85
Control (Conventional)	25	55.90 ± 7.10	55.90 ± 7.10	55.90 ± 7.10

Information

1. Score 0-100 (performance rubric: body position, arms, legs, breathing, coordination)
2. Gain= posttest rate-pretest rate-rate Based on table 3 above, it shows that in both groups the gain was greater in the VR group.

Table 4. Paired Sample t-test Results (Within Groups)

Group	t-count	Mr. (p)	Information
Experiment (VR)	14,32	0,000	Significant Improvement
Control (Convention)	8,41	0,000	Significant Improvement

Based on table 4. above, it shows that both groups experienced a significant increase from pretest to posttest ($p<0.05$), but the magnitude of the increase in the VR group was higher.

Table 5. Comparison of Gain Between Groups (Independent Sample t-test)

Group	Meian Gain Experiment	Median Gain Control	t-count	Mr. (p)	Information
Experiment (VR)	21,80	12,20	4,67	0,000	VR is significantly more effective

Difference in gain between the experimental and control groups significant ($p < 0.05$), shows that VR-based learning models are more effective in improving breaststroke swimming skills.

Table 6. Effect Size (Cohen's d)

Comparison	Cohen's d	Effect Size Category
VR vs. Conventional (Gain Score)	0.92	Large

The value of d = 0.92 indicates big influence. The use of VR to improve breaststroke swimming skills compared to conventional methods. The analysis results showed a significant increase in breaststroke swimming skills in both groups after treatment. However, the group participating in VR-based learning achieved a higher increase than the conventional group. The difference in gain between groups confirmed that the difference was statistically significant, with a large effect size. These findings confirm that VR integration is effective in improving movement comprehension and the quality of breaststroke swimming technique execution. The results of the study are then illustrated through the following bar graph of the pretest-posttest Breaststroke Swimming Skills.

Figure 1. Bar chart of pretest-posttest breaststroke swimming skills

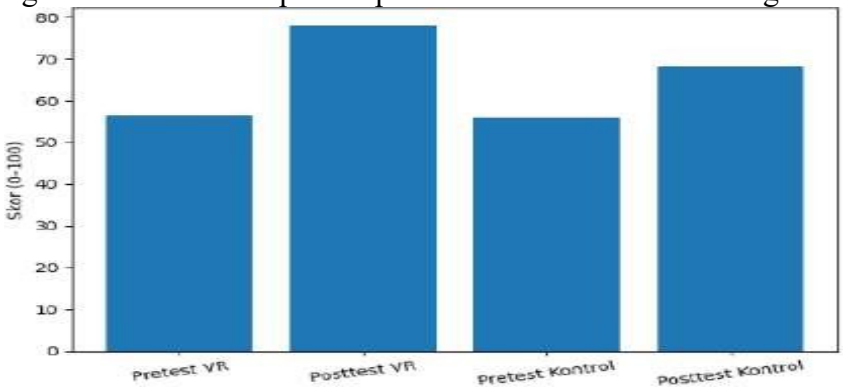

Figure 1. Bar Chart Research Data

Discussion

The results of the study indicate that the implementation of a Virtual Reality (VR)-based breaststroke swimming learning model provides greater skill improvement compared to conventional learning. This finding confirms that the integration of immersive technology can enrich students' learning experiences in understanding and practicing complex motor skills. VR allows students to observe breaststroke swimming techniques visually, in detail, and repeatedly from various perspectives, thereby strengthening the observation phase before direct practice in the pool. This mechanism is in line with motor learning principles that emphasize the importance of observing movement models (observational learning) and strengthening mental representations of movements

(motor imagery) before movement execution.

The more prominent improvement in motor coordination and arm movements in the VR group indicates that three-dimensional visualization helped students understand the sequence and synchronization between movement components. Coordination in breaststroke requires the integration of the arm pull clearer temporal (timing) and spatial (body position in the water) picture, thus minimizing technical errors during practice in the pool. This explains why the VR group's score gain was higher than the conventional group, which relied solely on instructor demonstrations and limited observation in the dynamic pool environment.

In addition to the cognitive-motor aspects, the improved outcomes in the VR group can also be understood from an affective and motivational perspective. VR media is immersive and interactive, increasing students' attention, engagement, and confidence before practicing in the water. Students can "try to understand" the movements without the pressure of failure in the pool, potentially reducing initial anxiety, especially for beginners, and increasing mental readiness during practice. This readiness contributes to more focused and effective practice, ultimately resulting in improved skill performance.

Although the control group also showed significant improvement, the magnitude of the improvement was relatively lower. This suggests that conventional methods remain effective as a basic approach to swimming learning, particularly through demonstration and repeated practice. However, limitations of conventional methods lie in the lack of opportunities for students to observe detailed movements closely, consistently, and repeatedly according to individual needs. Therefore, VR serves as a complementary tool that enhances the pre-practice phase, not a substitute for in-water practice. Integrating VR before pool sessions appears to be an optimal strategy for increasing the efficiency of swimming technique learning.

The practical implication of these findings is that swimming lecturers can integrate VR as a supporting medium during technique orientation, reinforcement of movement concepts, and remediation of technique errors. A blended approach between VR and hands-on practice in the pool has the potential to improve learning quality, especially in large classes with limited practice time. However, VR implementation requires consideration of infrastructure readiness, the availability of content appropriate to learning objectives, and lecturer training to ensure technology use remains oriented toward achieving movement competency.

This study has limitations, including the relatively short treatment duration and limited number of subjects, so generalization of the findings requires caution. Furthermore, this study did not explore the long-term impact of VR use on swimming skill retention. Therefore, further research is recommended to test the effectiveness of VR over a longer period, at different skill levels, and combine it with biomechanical analysis or video-based feedback to enhance the quality of swimming technique learning.

D. Conclusion

Based on the research results, it can be concluded that the Virtual Reality (VR)-based breaststroke learning model is proven to be more effective than conventional learning in improving students' breaststroke skills. The application of VR provides significant improvements in the quality of technical performance, particularly in aspects of motor coordination, arm movement, and breathing synchronization. The three-dimensional visualization of the technique and the opportunity for repeated observation through VR help students develop a better understanding of the

movements before practicing in the pool, resulting in a more efficient and focused training process.

While conventional learning still has a positive impact on skill development, the integration of VR as a supporting medium has been shown to enrich the learning experience and enhance students' cognitive, motor, and motivational readiness. Therefore, the use of VR is not intended to replace hands-on practice in the pool, but rather serves as a strategic complement that strengthens the pre-practice phase and technique reinforcement of breaststroke learning.

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F. Conflict of Interest

The authors declare that this research was funded through internal institutional grants. The grantors were not involved in the study design, data collection, analysis and interpretation of the results, or the decision to publish this article. Therefore, there are no conflicts of interest, either financial or non-financial, that could affect the objectivity of the research.

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