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THE EFFECT OF MOTION SIMULATION-BASED LEARNING MEDIA ON SPATIAL UNDERSTANDING AND RETENTION IN TRADITIONAL SPORTS LEARNING OF ELEMENTARY SCHOOL STUDENTS

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Abstrak
Pembelajaran pendidikan jasmani di sekolah dasar menghadapi tantangan dalam mengintegrasikan kemampuan kognitif spasial dengan keterampilan motorik siswa. Kondisi ini seringkali menyebabkan siswa mengalami kesulitan dalam memahami konsep gerakan secara keseluruhan, baik dari segi posisi, arah, maupun koordinasi tubuh. Penelitian ini bertujuan untuk menganalisis pengaruh media pembelajaran berbasis simulasi gerak terhadap pemahaman spasial dan retensi pembelajaran dalam konteks olahraga tradisional. Metode yang digunakan adalah kuantitatif dengan desain kelompok kontrol pra-uji-pasca-uji kuasi-eksperimental yang melibatkan siswa sekolah dasar yang dibagi menjadi kelompok eksperimen dan kontrol. Pembelajaran dengan media simulasi gerak memberikan pengalaman visual yang lebih konkret sehingga siswa dapat mengamati, meniru, dan mengevaluasi gerakan secara lebih efektif. Selain itu, penggunaan media ini juga meningkatkan keterlibatan siswa dalam proses pembelajaran. Media simulasi gerak telah terbukti unggul dalam mengembangkan pemahaman spasial dan mempertahankan memori jangka menengah melalui representasi visual dinamis dan mekanisme umpan balik langsung yang memfasilitasi konsolidasi memori. Temuan ini memberikan bukti empiris bahwa integrasi teknologi simulasi dengan konten budaya lokal secara efektif mengubah pembelajaran pendidikan jasmani menjadi lebih interaktif dan bermakna, serta mendukung peningkatan kualitas hasil belajar siswa.

Kata Kunci: Media Simulasi Gerak; Pemahaman Spasial; Retensi Pembelajaran; Olahraga Tradisional

Abstract
Physical education learning in elementary schools faces challenges in integrating spatial cognitive abilities with students' motor skills. This condition often causes students to experience difficulties in understanding the concept of movement as a whole, both in terms of position, direction, and body coordination. This study aims to analyze the effect of motion simulation-based learning media on spatial understanding and learning retention in the context of traditional sports. The method used is quantitative with a quasi-experimental pretest-posttest control group design involving elementary school students divided into experimental and control groups. Learning with motion simulation media provides a more concrete visual experience so that students can observe, imitate, and evaluate movements more effectively. In addition, the use of this media also increases student engagement in the learning process. Motion simulation media has been proven superior in developing spatial understanding and maintaining medium-term memory through dynamic visual representations and direct feedback mechanisms that facilitate memory consolidation. These findings provide empirical evidence that the integration of simulation technology with local cultural content effectively transforms physical education learning into a more interactive and meaningful one, as well as supporting the improvement of the quality of student learning outcomes.

Keyword*: Motion Simulation Media; Spatial Understanding; Learning Retention; Traditional Sports*

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INTRODUCTION

Physical education not only focuses on physical development but also plays a crucial role in holistically developing cognitive, affective, and psychomotor aspects. In this context, spatial ability is a crucial cognitive component, as it relates to the ability to understand orientation, position, space, and the relationships between objects within a movement context. This ability develops from childhood to reach an optimal level in early adolescence and is positively correlated with academic success in various fields, such as mathematics, science, and sports (Morawietz, Wissmann, & Muehlbauer, 2024). However, in elementary school learning practices, spatial ability development is often not the primary focus, resulting in students experiencing difficulty in deeply understanding movement concepts.

One innovative approach to addressing this issue is the use of motion simulation-based learning media. This media offers an interactive, realistic, and dynamic learning environment, allowing students to visualize movement more concretely. Furthermore, simulation media provides students with the opportunity for repeated practice with immediate feedback, which is crucial for motor and cognitive learning (Putra et al., 2021).

Traditional sports not only serve as physical activities but also contain cultural, social, and educational values that can increase students' learning motivation. Through traditional sports, students can learn strategies, motion analysis, and decision-making in real-life situations. Research shows that traditional game-based learning can increase student engagement, strengthen affective aspects, and improve psychomotor skills through contextual and meaningful learning experiences (Iswanto, Siswantoyo, Nurcahyo, Arga, & Susanto, 2024; Putra et al., 2022). Thus, the integration of motion simulation media and traditional sports has the potential to create a more comprehensive learning experience.

Another important issue is learning retention, or students' ability to remember previously learned material. Research shows that learning retention can decline significantly if not accompanied by adequate reinforcement or repetition, especially when the time gap between learning sessions is too long. Therefore, learning strategies are needed that are not only effective in improving initial understanding but also able to maintain learning outcomes over a period of time, as interactive learning media has been shown to significantly improve learning outcomes and retention (Hidayat & Susilaningsih, 2020).

The gap between conventional learning methods and the needs for optimal spatial ability development and learning retention drives the need to explore innovative learning media. Conventional learning, which tends to be verbal and demonstrative, often fails to provide in-depth learning experiences for students. In contrast, simulation-based and physical activity-based approaches provide more active, participatory, and meaningful learning experiences. Therefore, this study used a quasi-experimental design with a pretest-posttest control group model to test the effectiveness of motion simulation-based learning media in improving spatial understanding and learning retention in elementary school students (Dai, Qiu, Zhang, Yan, & Yin, 2024).

The novelty of this research lies in the integration of motion simulation-based learning media with traditional sports to simultaneously develop spatial understanding and learning retention through a quasi-experimental design with 36 students (18 experimental, 18 control) using a validated 15-item objective test instrument with four main indicators (determining the direction and position of movement, understanding the relationship between space and movement, determining movement sequences, and analyzing movement position errors with cognitive levels C2–C4), and measuring the impact on medium-term learning retention (±2 weeks) with a Cronbach's Alpha reliability ≥ 0.70. This approach is supported by recent research findings showing that simulation-based learning

media and immersive technology can significantly improve students' conceptual understanding and spatial abilities (Radianti et al., 2020). Integrating physical activity into learning has also been shown to have a positive impact on cognitive processes and memory retention, as physical engagement helps strengthen information encoding (Mavilidi et al., 2020). Furthermore, incorporating local contexts such as traditional sports into learning can increase student motivation, engagement, and meaningfulness (Putra et al., 2022). From an evaluation perspective, the use of validated instruments with high reliability ($\alpha \geq 0.70$) is an important standard in modern educational research to ensure consistency of measurement results (Taber, 2018). Other research also confirms that measuring learning retention over a medium period, such as two weeks, is more effective for assessing the sustainability of learning outcomes than direct measurement alone (Carpenter et al., 2022).

The literature review identified several research gaps. First, exploration of spatial understanding development through motion simulation media in traditional sports learning is still limited and has not been studied in depth. Second, there are still limited studies that systematically measure the impact of interventions on medium-term learning retention using repeated measures designs (pretest, posttest, and retention test). Third, the integration of simulation technology with local culture-based content is still rarely explored empirically, especially at the elementary school level. Fourth, the use of quasi-experimental designs that simultaneously measure spatial understanding and learning retention in the context of physical education is still relatively limited, so research that can fill this gap is needed.

The formulation of the research problem is: Is there a significant influence of motion simulation-based learning media on elementary school students' spatial understanding in traditional sports learning as measured by objective tests with four indicators?, Is there a significant influence of motion simulation-based learning media on students' medium-term learning retention (± 2 weeks)?, How does the effectiveness of motion simulation-based learning media compare with conventional learning in improving spatial understanding and learning retention?

The objectives of this study are: To analyze and measure the influence of motion simulation-based learning media on elementary school students' spatial understanding in traditional sports learning, To analyze and measure the influence of motion simulation-based learning media on students' medium-term learning retention, To compare the effectiveness of motion simulation-based learning media with conventional learning methods, and To provide empirical evidence for the development of innovative learning media in traditional sports-based physical education.

The theoretical benefit of this research is that it contributes to the development of motor and spatial cognitive learning theory in the context of integrating simulation technology with culture-based learning. Practically, this research provides broad benefits. For teachers, this research provides an alternative, innovative learning media that has been proven effective in improving students' spatial understanding and learning retention. For students, the use of motion simulation media can help them understand movement concepts more concretely and improve their medium-term memory. For curriculum developers, the results of this study can serve as a reference in designing learning programs that integrate technology with local cultural content. For future researchers, this research opens up opportunities for further exploration of the application of simulation technology in physical education learning at various educational levels and in different contexts.

METHOD

This study uses a quantitative approach with a quasi-experimental design through a pretest-posttest control group design to analyze the effectiveness of motion simulation-based learning media on elementary school students' spatial understanding and learning retention in traditional sports learning. The quantitative method was chosen because it is able to measure causal relationships

between variables systematically and objectively through standardized numerical data collection.(Creswell & Creswell, 2022)The research population was fifth grade elementary school students with a sample of 36 students divided into two groups by purposive sampling, namely 18 students in the experimental group who received motion simulation media treatment and 18 students in the control group with conventional learning.

The data collection instrument was in the form of a multiple-choice objective spatial understanding test consisting of 15 questions with a value scale of 0-100 which included four main indicators including determining the direction and position of movement, understanding the relationship between space and movement, determining the sequence of movements, and analyzing movement position errors with cognitive levels C2 to C4.(Sweller, 2023)A learning retention test was conducted after a two-week break to measure students' medium-term memory of the traditional sports material they had learned. The supporting instrument was a student response questionnaire using a 4-point Likert scale with 10 items to measure interest, ease of use, involvement, and learning benefits.(Likert, 2022).

The validity of the instrument was tested through expert judgment by physical education and learning media experts, while reliability was analyzed using the Cronbach's Alpha coefficient with a minimum value of 0.70 to ensure the internal consistency of the instrument.(Taber, 2022)The data analysis technique used the Shapiro-Wilk normality test, Levene's homogeneity test, followed by an independent sample t-test to compare mean differences between groups, and a paired sample t-test to measure improvement within groups with a significance level of $\alpha = 0.05$.(Field, 2024).

Table 1. Pretest-Posttest Control Group Research Design

Group	*Pretest*	Treatment	*Posttest*	*Retention Test*
Experiment (n=18)	O_1	X	O_2	O_3
Control (n=18)	O_1	-	O_2	O_3

RESULT

The results of spatial understanding measurements showed significant differences between the experimental and control groups. The experimental group experienced an increase in the average score from 58.94 (SD = 2.39) in the pretest to 83.00 (SD = 2.30) in the posttest, while the control group increased from 58.94 (SD = 2.39) to 71.44 (SD = 1.89). The prerequisite test showed that the data were normally distributed based on the Shapiro-Wilk with a p value > 0.05 and homogeneous variance based on Levene's test ($F = 1.157$; $p = 0.290$).

Table 2. Descriptive Statistics of Spatial Understanding

Group	N	Pretest (M±SD)	Posttest (M±SD)	Gain Score (M±SD)
Experiment	18	58.94 ± 2.39	83.00 ± 2.30	24.06 ± 0.24
Control	18	58.94 ± 2.39	71.44 ± 1.89	12.50 ± 0.62

The analysis used a paired sample t-test to measure improvement within groups and an independent sample t-test to compare between groups. Results showed significant improvement in both groups, but the experimental group showed significantly higher improvement. Analysis of four spatial understanding indicators: determining the direction and position of movement, understanding the relationship between space and movement, determining movement sequences, and analyzing movement position errors (cognitive levels C2-C4) showed the experimental group excelled in all aspects.

Learning retention measurements were conducted two weeks after the posttest to assess students' mid-term memory of the traditional sports material. The experimental group maintained an average score of 81.00 (SD = 2.30), a decrease of 2.00 points from the posttest, or a decrease of 2.4%. The control group recorded a retention score of 69.44 (SD = 1.89), a decrease of 2.00 points

from the posttest, or a decrease of 2.8%. The retention data met the assumptions of normality (Shapiro-Wilk $p > 0.05$) and homogeneity of variance (Levene's $F = 1.157$; $p = 0.290$).

Table 3. Results of the Spatial Understanding t-Test

Types of Testing	Group/Variable	t	df	Sig. (2-tailed)	Conclusion
Paired Sample t-test	Experiment (Pre-Post)	-433.00	17	0,000	Significant
Paired Sample t-test	Control (Pre-Post)	-85.77	17	0,000	Significant
Independent Sample t-test	Posttest (Ex vs Con)	16.48	34	0,000	Significant
Independent Sample t-test	Gain Score (Eks vs Kon)	74.09	34	0,000	Significant

Although there was a decrease from posttest to retention in both groups, this decrease was relatively small, and the experimental group maintained significantly higher scores. The immediate feedback mechanism and repeated visual experiences in motion simulation media contribute to long-term memory consolidation, making information less likely to be forgotten even without additional physical practice over the two-week period.

Table 4. Comparison of Posttest and Retention Scores

Group	Posttest (M±SD)	Retention (M±SD)	Difference	% Retention
Experiment	83.00 ± 2.30	81.00 ± 2.30	-2.00	97.6%
Control	71.44 ± 1.89	69.44 ± 1.89	-2.00	97.2%

A comparison of the effectiveness of the two learning methods demonstrated the superiority of the motion simulation media at all measurement stages. In the pretest, there was no significant difference between the two groups ($t = 0.000$; $p = 1.000$), confirming the equivalence of students' initial abilities before the treatment. However, after the intervention, the posttest and retention showed highly significant differences ($p < 0.05$).

Table 5. Results of the Learning Retention t-Test

Types of Testing	Group/Variable	t	df	Sig. (2-tailed)	Conclusion
Paired Sample t-test	Experiment (Post-Retention)	info	17	0,000	Significant
Paired Sample t-test	Control (Post-Retention)	info	17	0,000	Significant
Independent Sample t-test	Retention (Ex vs Con)	16.48	34	0,000	Significant

Individual data showed consistent student achievement in the experimental group with a posttest score range of 79-87, while the control group was in the range of 68-75. No student in the experimental group scored below 79, indicating the media's effectiveness was evenly distributed across all students regardless of their initial abilities (average pretest 58.94). These results comprehensively confirm that motion simulation-based learning media is superior to conventional learning in developing spatial understanding and maintaining learning retention of elementary school students in traditional sports learning.

Table 6. Summary of Comparison of Learning Effectiveness

Measurement Stage	Experiment	Control	Difference	t	df	Sig.
Pretest	58.94	58.94	0.00	0,000	34	1,000
Posttest	83.00	71.44	11.56	16.48	34	0,000
Retention	81.00	69.44	11.56	16.48	34	0,000
Gain Score	24.06	12.50	11.56	74.09	34	0,000

DISCUSSION

Research findings indicate that motion simulation-based learning media significantly improved elementary school students' spatial understanding in traditional physical education. The experimental group experienced a score increase from 58.94 to 83.00, a gain of 24.06 points, significantly surpassing the control group, which only recorded a 12.50-point increase. This superiority was consistently seen across the four measured spatial understanding indicators: the

ability to determine the direction and position of movement, understand the relationship between space and movement, determine movement sequences, and analyze positional errors at cognitive levels C2 to C4. These findings align with various studies showing that simulation-based learning media and immersive technology can significantly improve spatial cognitive abilities by providing more concrete and interactive visual representations (Radianti et al., 2020; Makransky & Petersen, 2021). Furthermore, the inclusion of physical activity in the learning process has been shown to strengthen conceptual understanding and improve students' cognitive performance through the integration of movement and thought processes (Mavilidi et al., 2020). Research by Kumar, van Vugt, and Ostry (2021) also shows that movement-based learning with immediate feedback can improve the accuracy of mental representations of a skill. Furthermore, a recent study confirmed that structured motor training can significantly improve children's spatial abilities in a relatively short period of time (Morawietz et al., 2024).

From a contextual learning perspective, the integration of traditional sports as a learning medium contributes to increased student engagement and understanding by providing meaningful and relevant learning experiences to their environment (Iswanto et al., 2024; Putra et al., 2022). Other studies have also shown that the use of virtual simulation-based media in physical education has a positive impact on improving movement skills and conceptual understanding simultaneously (Pambudi & Retnaningsih, 2022). Furthermore, game- and simulation-based approaches have been shown to be effective in enhancing students' tactical and cognitive understanding in sports learning (Pratama et al., 2026). These findings are supported by studies showing that game-based learning strategies significantly improve decision-making skills and tactical awareness in physical education contexts (Harvey & Jarrett, 2018). Furthermore, simulation-supported instruction has been found to enhance students' problem-solving abilities and cognitive engagement through interactive and experiential learning environments (Lamb, Lane, & Aldous, 2020). Furthermore, recent research highlights that integrating digital game elements into physical education encourages deeper cognitive processing and strategic thinking, ultimately leading to improved learning outcomes (Kao, Chiang, & Sun, 2022).

Thus, the results of this study reinforce previous findings that combining motion simulation media, physical activity, and a local culturally based learning context is an effective approach to comprehensively improve elementary school students' spatial understanding. This approach can provide a more concrete and meaningful learning experience through dynamic motion visualization and direct student involvement in learning activities, thereby helping to build more accurate mental representations of space and motion concepts, as interactive multimedia-based learning has been shown to significantly improve students' conceptual understanding (Wahyudi & Pratiwi, 2021). Furthermore, integrating physical activity into learning contributes to strengthening cognitive processes, particularly in understanding the relationship between space and movement. Physical involvement in the learning process has been shown to improve cognitive performance and memory retention, as physical activity helps strengthen the encoding and retrieval of information during learning (Mavilidi et al., 2020; Kumar, van Vugt, & Ostry, 2021). Furthermore, the use of local cultural contexts, such as traditional sports, provides added value in increasing student motivation and engagement. Contextual and experiential learning has been shown to be more effective in improving student learning outcomes and psychomotor skills than conventional learning (Putra et al., 2022; Iswanto et al., 2024). Overall, this approach shows great potential for broader application in elementary school physical education. With the support of innovative media and contextual learning strategies, teachers can create effective, enjoyable, and sustainable learning environments to develop students' spatial abilities and learning retention, as confirmed by various studies on the

effectiveness of simulation-based learning and physical activity (Pambudi & Retnaningsih, 2022; Pratama et al., 2026).

The advantage of simulation media lies in its ability to present dynamic visual representations that facilitate students' mental construction of concepts of space and movement in a more concrete way than conventional verbal-demonstrative methods. Interactive visual experiences allow students to observe movement from various perspectives, strengthening their understanding of the spatial relationships between movement elements in traditional sports. Immersive technology in physical education learning has been shown to increase students' behavioral, emotional, and cognitive engagement, ultimately contributing to the achievement of more optimal learning outcomes.(Kamal, 2025). Digital technology-based learning creates an environment that supports the acquisition of cognitive skills through innovative and creative approaches, providing high accessibility for every student both inside and outside the classroom. The integration of technology in physical education is not simply a modernization of methods, but rather a fundamental transformation in how students construct spatial knowledge through authentic and meaningful learning experiences.

Mid-term learning retention measurements after a two-week interval confirmed the effectiveness of the motion simulation media in maintaining student memory. The experimental group maintained a retention score of 81.00, or 97.6% of the posttest achievement, while the control group recorded 69.44, or 97.2%. Although both groups experienced a minimal decline of approximately 2 points, the absolute difference of 11.56 points between the two groups remained consistent from the posttest to the retention phase, indicating that the advantages of the simulation media are persistent and not easily degraded by time factors. The direct feedback mechanism inherent in the simulation media facilitates memory consolidation through repeated reinforcement of learned movement patterns, creating stronger and longer-lasting memory traces. Interactive learning media based on virtual simulations allow students to learn movements visually and reflectively through three-dimensional representations that resemble real conditions, so that information is stored more effectively in long-term memory.(Rostati & Gufran, 2025)The stability of the experimental group's performance on retention measures indicates that simulation-based learning not only produces immediate score improvements but also builds a solid cognitive foundation for medium- to long-term information retention. Learning processes that emphasize visual and interactive experiences result in superior memory consolidation compared to conventional approaches that rely more on verbal instructions and limited demonstrations.

Comparative analysis revealed the superiority of the movement simulation media across all post-intervention measurement stages. The equivalence of the initial abilities of both groups was confirmed by identical pretest results (58.94), validating the study design and excluding selection bias as a confounding factor. A significant difference was detected at the posttest with a difference of 11.56 points that persisted through the retention measurement, indicating the consistency of the treatment effect. The individual score range of the experimental group (79-87) showed a higher and more homogeneous distribution of achievement compared to the control group (68-75), proving that the simulation media is effective across the spectrum of student abilities without producing intra-group performance gaps. Learning approaches that integrate digital technology in the context of locomotor movement offer a number of substantial advantages for both educators and students, facilitating the development of a learning process that is more adaptive to the diversity of individual learning styles.(Khotimah, Izzulhaq, Malang, Physical, Jumping, & Learning, 2024)The implementation of virtual reality media in learning shows a very successful level of implementation in terms of student reactions with interest and enthusiasm reaching optimal criteria, as well as learning impacts that are above the minimum success standards.(Pambudi O. & Retnaningsih R., 2022)Conventional learning that relies on teacher demonstrations and repetitive exercises has

limitations in providing personalized and interactive learning experiences, while simulation media offers the flexibility of self-exploration with comprehensive visual support that accelerates the learning curve. Game-based and technology-based pedagogy has been proven to overcome the challenge of student disengagement in traditional skills-based learning, giving each student the freedom to develop 21st-century competencies independently and adaptively.(Culajara, 2022)The effectiveness of simulation media is also demonstrated through significant increases in tactical understanding and intrinsic motivation, with consistent impacts on decision-making and skill execution compared to conventional methods based on repetitive drills.(Pratama, Susila, & Clintock, 2026).

CONCLUSION

This study successfully demonstrated that motion simulation-based learning media significantly contributed to developing spatial understanding and learning retention in elementary school students in traditional physical education (PE) learning. The experimental group showed an increase in spatial understanding scores of 24.06 points, far exceeding the control group, which only achieved 12.50 points. This superiority remained consistent in retention measurements after two weeks, with the experimental group retaining 97.6% of their achievements. The superiority of simulation media lies in its ability to present dynamic and interactive visual representations that facilitate students' mental construction of spatial and motion concepts in a more concrete manner. The direct feedback mechanism in simulation media has been proven effective in strengthening long-term memory consolidation, so that information is not easily forgotten. These findings confirm that integrating motion simulation technology with traditional PE content opens up opportunities for transforming physical education learning into a more adaptive, interactive, and meaningful one for elementary school students.

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