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Effectiveness Of Kinovea Application Integrated With The PJOK GEMBIRA Framework Through A Deep Learning Approach In Volleyball Learning At Public Elementary Schools In Penyaring

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Abstract

The demand for 21st-century educational innovation necessitates a paradigm shift in Physical Education, Sports, and Health (PJOK) from conventional, teacher-centered methods to interactive, student-centered learning. This study aims to describe the implementation and analyze the empirical effectiveness of the Kinovea application integrated with the PJOK GEMBIRA learning framework through a deep learning approach to improve basic volleyball skills among elementary school students. Employing a mixed-methods approach with an Explanatory Sequential design, the research utilized a quasi-experimental non-equivalent control group model for the quantitative phase, supported by qualitative observations and questionnaires. The population consisted of fifth-grade students from two public elementary schools in Penyaring, Sumbawa Regency, with a total sample of 40 students selected through total sampling (20 in the experimental group, 20 in the control group). Quantitative data analysis involved paired sample t-tests, independent sample t-tests, and N-Gain calculations, while qualitative data underwent systematic reduction and interpretation. The results demonstrate that the integrated Kinovea-PJOK GEMBIRA framework was implemented highly effectively. The experimental group's mean score increased significantly from 62.04 in the pretest to 87.59 in the posttest, yielding an N-Gain of 0.673 (Moderate-High category), whereas the control group's mean score rose from 49.44 to 65.93, with an N-Gain of 0.326. Statistical testing confirmed a significant difference between the two groups ($p < 0.001$). Qualitative findings revealed that 100% of students in the experimental group engaged actively, and

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95% effectively utilized the Kinovea visual feedback to analyze and correct their motor mechanics. In conclusion, the systematic integration of motion-analysis technology and deep learning frameworks significantly enhances the acquisition of basic volleyball skills, offering a robust, empirical model for modernizing physical education in elementary schools.

Keywords: Kinovea Application; PJOK GEMBIRA; Deep Learning; Volleyball Skills; Mixed Methods.

INTRODUCTION

21st-century education demands a paradigm shift in learning that focuses not only on knowledge acquisition but also on the development of critical thinking, creativity, collaboration, and communication skills. In this context, elementary school education plays a crucial role as a foundational stage in comprehensively shaping students' cognitive, affective, and psychomotor abilities.

One of the subjects contributing to the development of these three domains is Physical Education, Sports, and Health (PJOK). PJOK is not solely oriented toward improving physical fitness but also aims to develop students' motor skills, cognitive abilities, and social values. According to Kirk (2020), PJOK plays a strategic role in holistically integrating physical, cognitive, and social development within the learning process. However, in practice, PJOK instruction in elementary schools continues to face various challenges. Learning tends to be teacher-centered, providing insufficient space for active student participation. Furthermore, the limited provision of specific feedback makes it difficult for students to understand and correct their movement errors.

These issues are evident in volleyball instruction, particularly in the mastery of basic techniques such as passing, serving, and movement coordination. Based on preliminary observations conducted at State Elementary School 1 Penyaring and State Elementary School 2 Penyaring, students still experience difficulties in correctly understanding basic volleyball techniques. Students tend to merely imitate movements without grasping the underlying concepts or recognizing their technical errors, resulting in suboptimal motor skill proficiency.

This aligns with the perspective of Kirk (2020), who posits that PJOK plays a vital role in simultaneously and holistically developing students' physical competencies as well as their social and cognitive skills.

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Nevertheless, in practice, PJOK instruction in elementary schools still encounters numerous obstacles. Instruction tends to be conventional, teacher-centered, and underutilizes instructional media and technology. Despite this, conventional approaches remain widely used and are considered relevant. Methods such as lectures, face-to-face discussions, and in-class assignments maintain distinct advantages in fostering emotional connection, discipline, and an in-depth understanding of the material. Research by Qolbi and Fatimah (2021) indicates that limited face-to-face learning, particularly in thematic subjects such as mathematics, remains effective in helping students understand materials directly and more clearly.

On the other hand, there are inherent challenges in implementing both methods. Digital learning is frequently hindered by device limitations, internet connectivity issues, and low student digital literacy in certain regions. Meanwhile, conventional learning is often perceived as monotonous and inadequately equipped to optimally facilitate diverse student learning styles. This situation raises a critical question: which instructional approach is more effective in enhancing student engagement and comprehension—technology-based or conventional? Furthermore, to what extent can technology overcome the limitations of traditional methods, and how relevant is it in addressing the challenges of contemporary education?

This study aims to evaluate and compare the effectiveness of technology-based instructional strategies against conventional methods, particularly concerning the enhancement of student engagement and comprehension. It is anticipated that the findings of this research will serve as a reference for designing instructional strategies that are more aligned with student needs and current educational contexts.

These conditions lead to low student involvement and suboptimal comprehension of basic techniques in various sports, including volleyball. Students generally only mimic movements without understanding the underlying concepts or technical errors, preventing them from achieving maximal learning outcomes. This is corroborated by the research findings of Casey (2021), which demonstrate that PJOK instruction lacking technological integration and active student participation tends to result in superficial comprehension (surface learning).

The evolution of 21st-century education necessitates instructional innovations capable of integrating technology and fostering active student engagement. One technology that can be utilized in PJOK instruction is the Kinovea application, a software designed for visual motion analysis. Through this application, students can view, observe,

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and evaluate movements in greater detail, thereby making the learning process more interactive and reflective. Research conducted by Balsalobre and Carlos (2022) indicates that the use of video analysis in sports education can enhance technical understanding and provide more effective feedback to learners. In the context of motor learning, Schmidt and Lee (2021) assert that repeated observation of correct movements is crucial. Students who visually observe movement models tend to internalize motor patterns more rapidly than those relying solely on verbal instructions. This is highly relevant to the technical nature of volleyball, which requires movement visualization. Video analysis allows fast-paced sports movements to be broken down into micro-components (slow motion), enabling students to repeatedly observe detailed mechanics. This concretizes abstract concepts into tangible visual representations, assisting students in understanding "what" a correct movement is and "how" it should be executed properly.

In addition to utilizing technology, a systematic and student-centered instructional flow is necessary to make the learning process more meaningful. Student-centered learning focuses on the students' learning experiences and what they do to achieve learning objectives, rather than solely on what the teacher delivers (Indayania & Hartini, 2024). In this study, the researcher developed the PJOK GEMBIRA instructional flow, which encompasses a systematic progression: *Gali dan Eksplorasi* (Explore), *Muat Konten* (Load Content), *Buat Aktivitas* (Create Activity), *Ikuti Pemikiran Siswa* (Follow Student Thinking), *Rayakan* (Celebrate), and *Akhiri* (Conclude). An instructional flow is often defined as a series of systematic steps or processes designed to achieve learning objectives. This specific flow is designed to create an active, adaptive, and enjoyable learning environment while simultaneously providing space for students to think, reflect, and participate optimally. This concept aligns seamlessly with the student-centered learning approach, which emphasizes active student involvement in knowledge construction (Hattie, 2020).

Exploration during the initial stages of learning is critical as it builds curiosity, focuses attention, and triggers students' intrinsic motivation to learn. This process transforms students into active learners who independently construct conceptual understanding and assists teachers in identifying students' baseline capabilities. Meaningful learning content serves as the backbone of interaction, helping students connect new knowledge with pre-existing concepts. Engaging in activities during the learning process helps students link abstract concepts with concrete experiences, which strengthens neural pathways in the brain and enhances material retention. Furthermore, it makes the learning process more enjoyable, challenging, and engaging, thereby

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increasing students' physical and mental participation. This allows students to apply classroom theories to real-life contexts or the professional world—highly relevant to 21st-century skill requirements. Through student-driven activities, new thoughts, ideas, and concepts emerge, ultimately leading to a synthesized learning conclusion that aligns with the intended learning objectives.

The integration of the Kinovea application within the PJOK GEMBIRA instructional flow facilitates the creation of a learning environment rooted in a deep learning approach—an educational philosophy that emphasizes holistic conceptual understanding, active student engagement, and the capacity for critical reflection on the learning process. Within this approach, students do not merely execute physical movements; they also understand, analyze, and refine the skills being studied. According to Fullan (2021), deep learning is an educational process that compels students to think critically, reflect continuously, and apply acquired knowledge within real-world contexts.

Based on preliminary observations of volleyball instruction at State Elementary School 1 Penyaring and State Elementary School 2 Penyaring, it was found that the learning process remained heavily dominated by conventional methods. Teachers predominantly utilized lecture approaches and simple, front-of-class demonstrations, while students merely acted as passive recipients of information.

During learning activities, students tended to only watch and listen to the teacher's explanations without being given adequate opportunities to explore the skills hands-on. Two-way interaction between the teacher and students remained limited, resulting in suboptimal active student participation. Additionally, the use of varied and innovative instructional media was noticeably absent, rendering the learning experience less engaging and insufficiently challenging for the students.

This situation negatively impacted the students' conceptual understanding and mastery of basic volleyball skills. Consequently, students experienced difficulties in correctly grasping fundamental techniques such as passing and serving. Student involvement during the learning process remained demonstrably low; students appeared to lack enthusiasm and confidence when practicing movements. This was largely due to a lack of practical and collaborative learning experiences, which ultimately led to suboptimal educational outcomes.

Therefore, there is a pressing need for instructional innovations that can enhance active student engagement, provide more meaningful learning experiences, and develop motor skills through a more interactive and enjoyable approach, primarily through the utilization of technology.

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While numerous studies have investigated the utilization of technology in PJOK instruction, a significant research gap remains: there is a scarcity of research integrating motion analysis applications, such as Kinovea, with innovative, student-needs-based instructional flows and deep learning approaches, particularly at the elementary school level. Therefore, empirical research is required to comprehensively examine the integrated application of technology and pedagogical models within the context of elementary school physical education.

Based on the aforementioned rationale, instructional innovations capable of enhancing the effectiveness of PJOK learning through technology integration and student-centered pedagogy are highly necessary. Thus, this study was conducted to examine the effectiveness of integrating the Kinovea application within the PJOK GEMBIRA instructional flow through a deep learning approach in teaching volleyball at State Elementary School 1 Penyaring and State Elementary School 2 Penyaring. This study employs a mixed-methods approach to obtain a comprehensive overview of both the instructional outcomes and the ongoing learning processes.

LITERATURE REVIEW

Theoretical Foundation

This research is grounded in established theories of motor learning and educational technology integration. According to Schmidt and Lee's (2021) Motor Schema Theory, skill acquisition is heavily dependent on the quality and specificity of feedback (Knowledge of Results and Knowledge of Performance). Traditional physical education often fails to provide accurate Knowledge of Performance because human observation in real-time is limited. Visual feedback mechanisms bridge this gap by allowing learners to construct accurate cognitive representations of their physical movements.

The Concept of Deep Learning in Physical Education

Deep learning is defined as a pedagogical approach that encourages students to move beyond rote memorization or mechanical repetition toward a profound conceptual understanding. According to Fullan (2021), deep learning involves mindful engagement, where students connect new information to prior knowledge and apply it to complex, real-world scenarios. In the context of PJOK, deep learning transforms the student from a passive recipient of physical instructions into an active analyst of their own body mechanics. This involves observing a movement, understanding the biomechanical

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principles behind it (e.g., angle of the arms during a forearm pass), evaluating one's own execution, and making conscious adjustments.

Kinovea Application as a Pedagogical Tool

Kinovea is an open-source, 2D motion analysis software widely utilized in sports science and physical education. It facilitates advanced video analysis through features such as slow-motion playback, frame-by-frame progression, trajectory tracking, and angle measurement. Empirical studies (e.g., Balsalobre & Fernández, 2022) have consistently demonstrated that video analysis significantly enhances technical accuracy and movement comprehension. By integrating Kinovea into the physical education curriculum, instructors can provide objective, visual evidence of a student's performance, thereby minimizing the ambiguity often associated with verbal feedback and accelerating the motor learning process.

The PJOK GEMBIRA Framework

To ensure that technology is not utilized in a vacuum, the PJOK GEMBIRA framework was developed as a systematic, constructivist instructional model. The framework is structured as follows:

a. Elicit and Explore: Activating prior knowledge and stimulating intrinsic motivation through inquiry.
b. Load Content: Delivering structured conceptual knowledge using multimedia and visual models.
c. Create Activity: Engaging students in practical, varied physical exercises to build experiential knowledge.
d. Follow Student Thinking: Facilitating analytical thinking, where students use Kinovea to observe and critique their own movements.
e. Celebrate: Providing positive reinforcement and celebrating micro-improvements to build self-efficacy.
f. Conclude: Conducting a comprehensive reflection and summarizing the learning outcomes.

Basic Volleyball Skills in Elementary Education

Volleyball instruction at the elementary level focuses on foundational motor skills, specifically the forearm pass, overhead pass, and underhand serve. These skills require a complex interplay of hand-eye coordination, spatial awareness, and timing. Mastery of

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these fundamentals is a prerequisite for advanced gameplay. Traditional instructional limitations often hinder the development of these skills, necessitating a shift toward the visually augmented, reflective practices proposed in this study.

RESEARCH METHODOLOGY

Research Design

This study utilized a Mixed Methods approach with an Explanatory Sequential design (Creswell & Creswell, 2018). In this design, quantitative data collection and analysis are prioritized in the first phase to establish statistical evidence of efficacy. The second phase involves the collection of qualitative data to explain, contextualize, and deepen the understanding of the quantitative results. The quantitative component employed a quasi-experimental Nonequivalent Control Group Design, involving a pretest, a structured intervention, and a posttest.

Table 1. Research Design

Group	Pretest	Treatment	Posttest
Experimental (SDN 2 Penyaring)	O&sub1;	X (Kinovea + PJOK GEMBIRA + Deep Learning)	O&sub2;
Control (SDN 1 Penyaring)	O&sub3;	- (Conventional Instruction)	O&sub4;

Population and Sample

The population for this study comprised all fifth-grade students from SDN 1 Penyaring and SDN 2 Penyaring in the Moyo Utara District, Sumbawa Regency. A total sampling technique was employed, resulting in a sample size of 40 students. SDN 2 Penyaring (20 students) was designated as the experimental group, while SDN 1 Penyaring (20 students) served as the control group. Both schools share similar demographic profiles, curriculum standards, and baseline physical education facilities, ensuring a high degree of comparability.

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Research Variables and Instruments

The independent variable was the implementation of the Kinovea application integrated with the PJOK GEMBIRA framework via a deep learning approach. The dependent variable was the students' basic volleyball skills (forearm pass, overhead pass, and serve). Data collection utilized multiple triangulated instruments:

1. Skill Performance Test: A standardized psychomotor assessment rubric (scale 1-4) measuring the biomechanical accuracy of the passing and serving techniques during both pretest and posttest phases.
2. Observation Checklists: Structured qualitative observations conducted during the intervention to monitor student engagement, focus on visual feedback, and active movement correction.
3. Student Questionnaires: A 4-point Likert scale survey distributed post-intervention to assess students' perceived usefulness of the Kinovea software, their engagement levels, and their attitude toward the PJOK GEMBIRA framework.
4. Documentation: Photographs, video recordings, and Kinovea export files used to corroborate observational data.

All instruments were subjected to expert validation (content validity) by two independent academic specialists in Physical Education and Research Methodology, yielding a "Valid and Usable" status prior to deployment.

Data Analysis Techniques

Quantitative data were analyzed using descriptive and inferential statistics via IBM SPSS software. The analysis protocol included:

1. Normality and Homogeneity Tests: To verify that data met parametric assumptions.
2. Paired Sample t-Tests: To determine the internal pretest-posttest significance within each group.
3. Independent Sample t-Tests: To compare the post-intervention outcomes between the experimental and control groups.
4. N-Gain Score Analysis: To quantify the magnitude of improvement (effectiveness) using Hake's normalized gain formula.

Qualitative data from observations and questionnaires were analyzed descriptively using percentage distributions and thematic synthesis to explain the quantitative phenomena.

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RESULTS AND DISCUSSION

Descriptive Statistics of the Research Variables

The initial phase of data analysis involved computing the descriptive statistics for the basic volleyball skills of both groups prior to and following the respective interventions.

Table 1. Descriptive Statistics of Basic Volleyball Skills

Group	Statistic	Pretest	Posttest	Mean Increase
Control (SDN 1)	Mean	49.44	65.93	16.49 points
	Std. Deviation	5.41	3.09	
	Minimum	40.74	59.26	
	Maximum	59.26	70.37	
Experimental (SDN 2)	Mean	62.04	87.59	25.55 points
	Std. Deviation	5.49	4.85	
	Minimum	51.85	77.78	
	Maximum	70.37	96.30	

Source: data processed, 2026

The descriptive data reveals that while both groups demonstrated improvement, the experimental group exhibited a substantially higher mean increase (25.55 points) compared to the control group (16.49 points). Furthermore, the experimental group's final mean score of 87.59 indicates a high level of mastery in basic volleyball skills.

Hypothesis Testing

Paired Sample t-Test

To determine whether the improvements within each group were statistically significant, paired sample t-tests were conducted.

Table 2. Paired Sample t-Test Results for Internal Group Improvement

Group	Mean Diff.	t-value	df	Sig. (2-tailed)	Conclusion
Control (Pre vs. Post)	-16.48	-16.698	19	0.000	Significant Improvement
Experimental (Pre vs. Post)	-25.55	-15.250	19	0.000	Significant Improvement

Source: data processed, 2026

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Both groups showed significant internal improvement ($p < 0.001$). However, to assess the true effectiveness of the Kinovea-integrated framework, a comparison between the two groups was necessary.

Independent Sample t-Test

An independent sample t-test was utilized to compare the posttest outcomes of the experimental and control groups. Levene's Test for Equality of Variances indicated heterogeneous variances ($F = 5.077$, $p = 0.030$); thus, the "Equal variances not assumed" statistics were interpreted.

Table 3. Independent Sample t-Test Results (Gain Scores Comparison)

Test Variable	Mean Difference	t-value	df	Sig. (2-tailed)
Gain Scores (Exp vs. Control)	9.077	-4.668	30.756	0.000

Source: data processed, 2026

The analysis yielded a t-value of -4.668 with a significance of 0.000 ($p < 0.05$). This confirms the rejection of the null hypothesis (H&sub0;) and the acceptance of the alternative hypothesis (H&sub1;). There is a highly significant difference in skill acquisition, proving that the technology-integrated deep learning approach is superior to conventional instruction.

N-Gain Analysis

To quantify the magnitude of pedagogical effectiveness, the normalized gain (N-Gain) was calculated.

Table 4. Normalized Gain (N-Gain)
Analysis of Pedagogical Effectiveness

Group	N-Gain Score	Category
Experimental	0.673	Moderate-High
Control	0.326	Moderate

Source: data processed, 2026

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The experimental group's N-Gain of 0.673 borders the "High" effectiveness threshold, starkly contrasting with the control group's lower-moderate gain, further validating the empirical efficacy of the intervention.

Qualitative Findings and Integration (Mixed Methods)

The quantitative dominance of the experimental group is systematically explained by the qualitative observations and questionnaire data. Observational data revealed that 100% of students in the experimental group actively participated in the physical drills. Crucially, 95% demonstrated high focus when interacting with the Kinovea video playback, 90% successfully self-identified specific biomechanical errors (e.g., improper arm angle during forearm passes), and 85% successfully executed movement corrections on subsequent attempts based on that visual feedback.

The post-intervention questionnaire distributed to the experimental group yielded a cumulative score of 615 out of a maximum 640, translating to a 96.09% positivity rate (Categorized as "Excellent"). Students reported that the visual evidence provided by Kinovea demystified abstract technical instructions. Instead of merely being told their arms were bent, they could empirically view the angle of flexion and correlate it with the ball's erratic trajectory.

DISCUSSION

The findings of this study unequivocally confirm that integrating the Kinovea motion analysis application within the PJOK GEMBIRA framework via a deep learning approach significantly enhances the acquisition of basic volleyball skills. This empirical success can be attributed to several systematically aligned pedagogical factors.

Firstly, the provision of objective, visual feedback via Kinovea directly addresses the limitations of conventional instruction. Consistent with the principles of Motor Learning Theory, learners process visual information regarding their own body mechanics much more rapidly than verbal descriptions. The slow-motion and angle-measurement features allowed elementary students to transition from abstract guessing to concrete, logical biomechanical adjustments.

Secondly, the PJOK GEMBIRA framework provided a structured, constructivist environment that facilitated this technological integration. Rather than using technology passively, the framework's "Ikuti Pemikiran Siswa" (Follow Student Thinking) stage demanded active cognitive engagement. Students were not merely physical actors; they became analysts of their own performance. This aligns perfectly with the deep learning

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paradigm, which posits that learning is most effective when it is mindful, meaningful, and joyful.

Finally, the psychological impact of this methodology cannot be overstated. The "Rayakan" (Celebrate) phase of the framework, coupled with the immediate, visible proof of improvement provided by Kinovea, fostered high levels of self-efficacy and intrinsic motivation. The mixed-methods triangulation confirms that the statistical supremacy of the experimental group was a direct result of increased cognitive engagement, precise visual feedback, and a highly motivational learning environment.

CONCLUSION

Based on a rigorous, empirical analysis employing a mixed-methods design, this study concludes that the integration of the Kinovea application within the PJOK GEMBIRA framework through a deep learning approach is highly effective in improving basic volleyball skills among elementary school students. The experimental group demonstrated a statistically significant superiority in skill acquisition (mean increase of 25.55 points, N-Gain of 0.673) compared to the conventional control group (mean increase of 16.49 points, N-Gain of 0.326).

The technology-augmented, deep learning framework successfully transformed the pedagogical environment from passive reception to active, reflective analysis. By leveraging visual feedback, students achieved a profound, logical understanding of their motor mechanics, translating directly into superior physical execution.

It is highly recommended that physical education educators adopt motion analysis technologies like Kinovea, coupled with structured, student-centered frameworks like PJOK GEMBIRA, to modernize sports instruction. Institutional support in providing necessary digital infrastructure is vital. Future research should expand this model to other complex motor skills, broader demographics, and investigate longitudinal retention of skills acquired through this deep learning methodology.

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