

Comparison of Learning Motivation with Digital and Analog ROTAK in Junior High School Physical Education

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Abstract

Learning motivation is important for sustaining students' participation and engagement in Physical Education, Sports, and Health. This study compared learning-motivation outcomes among seventh-grade students participating in instruction using Digital ROTAK and Analog ROTAK, two formats of a researcher-developed educational spinning-wheel game. A quasi-experimental nonequivalent pretest-posttest comparison-group design was conducted at SMP Satu Atap 4 Gunungsari, Indonesia. All 62 seventh-grade students from two existing classes participated, with 31 students receiving Digital ROTAK instruction and 31 receiving Analog ROTAK instruction. Both groups completed four instructional sessions of 2 × 40 minutes. Learning motivation was measured using a 20-item, four-point Likert questionnaire covering perseverance, interest and attention, readiness and active participation, self-confidence, and enthusiasm and participation. Motivation increased significantly in the Digital ROTAK group (mean change = 14.00, 95% CI [11.84, 16.16], $t(30) = 13.24$, $p < .001$, $d_z = 2.38$) and the Analog ROTAK group (mean change = 12.74, 95% CI [11.22, 14.26], $t(30) = 17.11$, $p < .001$, $d_z = 3.07$). However, the between-group difference in pretest-posttest change was not significant (mean difference = 1.26, 95% CI [-1.34, 3.85], Welch's $t(53.89) = 0.97$, $p = .335$, $d = 0.25$). After adjustment for baseline motivation, Digital ROTAK showed a higher adjusted posttest mean than Analog ROTAK (71.01 vs. 65.80), with an adjusted difference of 5.21 points, 95% CI [3.42, 7.01], $F(1, 59) = 33.78$, $p < .001$, partial $\eta^2 = .364$. Both ROTAK formats were associated with increased motivation during the study period, while Digital ROTAK was associated with a higher baseline-adjusted posttest score. These findings should be interpreted cautiously because the study used nonrandomized intact classes, a single school, and no conventional-instruction control group.

Keywords: Learning Motivation; Game-Based Learning; Digital ROTAK; Analog ROTAK; Physical Education; Quasi-Experimental Study

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INTRODUCTION

Physical Education, Sports, and Health (*Pendidikan Jasmani, Olahraga, dan Kesehatan* [PJOK]) is a core component of school education that contributes to students' physical, cognitive, social, emotional, and character development (Blas et al., 2024; Camacho-Sánchez et al., 2023; Khasyia et al., 2025; Lamat et al., 2025; Mo et al., 2024; Mufarrihah & Ridwan, 2026; Saputro et al., 2026; Siti et al., 2024). Unlike subjects in which learning is predominantly conceptual, PJOK requires students to participate actively in movement-based activities, interact with peers, respond to instructional challenges, and sustain effort during practical learning tasks. Consequently,

successful PJOK instruction depends not only on curriculum content and teacher competence but also on students' willingness to participate, persist, attend to instructional tasks, and engage confidently in physical activities. Low motivation can be reflected in passive participation, reduced confidence, reluctance to perform movement tasks, and limited classroom engagement (Saputro et al., 2026; Sepriani et al., 2025; Siti et al., 2024).

Learning motivation is therefore particularly relevant in Physical Education because it influences the direction, intensity, and persistence of students' behavior during instruction (Khasyia et al., 2025; Lamat et al., 2025; Mo et al., 2024; Mufarrihah & Ridwan, 2026). In PJOK, motivation encompasses more than striving for academic achievement; it also involves students' willingness to attempt movement tasks, remain engaged when activities are challenging, participate with peers, and continue investing effort during lessons.

Self-Determination Theory (SDT) provides an established framework for understanding motivation in Physical Education. SDT proposes that more autonomous forms of motivation are supported when learning environments facilitate autonomy, competence, and relatedness. A systematic review and meta-analysis of 265 studies in school Physical Education found that satisfaction of these basic psychological needs was positively related to autonomous motivation and adaptive student outcomes (Vasconcellos et al., 2020). Qualitative evidence likewise indicates that choice, appropriate challenge, competence development, and supportive peer relationships can contribute to positive participation and affective experiences in Physical Education (White et al., 2021). These propositions are consistent with research emphasizing supportive learning environments, feedback, active participation, and teacher-student interaction (Bergentoft et al., 2024; Chen et al., 2014; Liang et al., 2023; Xu et al., 2025; Zha et al., 2025). The five content domains measured in the present study – perseverance in learning, interest and attention, readiness and active participation, self-confidence, and enthusiasm and participation – are treated as operational indicators of learning motivation rather than direct measures of autonomy, competence, or relatedness.

The practical need for a more engaging instructional approach was identified through preliminary diagnostic observations at SMP Satu Atap 4 Gunungsari. Observations conducted jointly by the PJOK teacher and researchers before the intervention indicated recurrent passive participation, including limited involvement in movement tasks and group discussions, weak responsiveness to teacher instructions, and low visible enthusiasm during learning activities. These observations were used to identify the instructional problem and were not treated as formal outcome data. PJOK instruction also relied substantially on teacher-directed explanation and printed learning resources. The school operated with limited instructional facilities, making it important to identify learning media that could promote active participation while remaining feasible under different levels of technological availability.

One approach that may address motivational challenges in Physical Education is game-based learning. Educational games can embed instructional tasks within challenges, rules, choices, cooperation, competition, and immediate participation, thereby changing how students interact with learning activities. Previous studies and reviews report generally favorable effects of game-based learning and gamification on motivation, engagement, enjoyment, and participation in Physical Education

(Camacho-Sánchez et al., 2023; Li & Kangas, 2026; Zhao et al., 2024). Systematic reviews nevertheless emphasize heterogeneity in intervention designs, educational levels, and outcome measures (Arufe-Giráldez et al., 2022; Sal-de-Rellán et al., 2025).

Empirical research with school-aged students provides further support for examining game-based approaches. Fernández-Río et al. (2022) reported favorable post-intervention outcomes in intrinsic motivation, autonomy, competence, relatedness, and intention to remain physically active among secondary-school students participating in a gamified Physical Education program. Sotos-Martínez et al. (2024) similarly reported improvements in basic psychological needs and intrinsic motivation following an eight-session gamified intervention with secondary-school students. These studies primarily contrasted gamified instruction with traditional or nongamified approaches, rather than comparing two equivalent versions of the same game delivered through different media.

Technological development has expanded the range of instructional media available in Physical Education. Digital tools can support interactive presentation, visualization, personalized information, feedback, and gamified learning experiences (Jiang & Ning, 2022; Mackenbrock & Kleinert, 2026; Martín-Rodríguez & Madrigal-Cerezo, 2025; Zhong et al., 2025). At the same time, technology-enhanced Physical Education depends on implementation quality, teacher readiness, and equitable access to resources. Non-digital games remain educationally relevant because they can provide direct manipulation, visible turn-taking, peer communication, and face-to-face participation without requiring computers or projectors. A comparative meta-analysis of educational games found positive effects for both digital and non-digital formats (Talan et al., 2020), while a matched-format study outside Physical Education reported different motivational and learning advantages for digital and non-digital games (Xiang et al., 2025).

The distinction between digital and non-digital formats is particularly relevant in rural and resource-constrained settings. Evidence on rural youth indicates that digital technologies may support participation and motivation while also introducing infrastructure and equity constraints (Camacho-Illana et al., 2026). Accordingly, a direct comparison between a technology-supported medium and a functionally similar physical alternative can provide practically relevant evidence for schools that must balance instructional innovation with available resources. Table 1 summarizes representative studies most directly related to game-based motivation, digital technology, and media-format comparisons.

As shown in Table 1, the literature provides substantial evidence that game-based and technology-supported Physical Education can influence motivation, but three gaps remain relevant. First, most Physical Education studies compare game-based or digital instruction with conventional teaching rather than digital and physical versions of the same instructional game. Second, resource-constrained settings introduce additional questions concerning infrastructure, accessibility, and sustainability. Third, when content, instructional procedures, and technology change simultaneously, it is difficult to isolate the contribution of presentation format.

The present study addresses these issues using ROTAK (Roda Putar Edukatif; Educational Spinning Wheel), a researcher-developed wheel-based educational game in which students obtain questions, movement challenges, and learning tasks through a spinning-wheel activity. Digital ROTAK presents the wheel and task-selection process through a digital interface displayed using a computer and LCD projector,

whereas Analog ROTAK uses a manually operated physical spinning wheel. Both formats use the same learning objectives, competency targets, instructional content, question and movement-task pool, lesson duration, teacher, and overall instructional sequence.

Table 1. Selected Previous Studies and Positioning of the Present Study

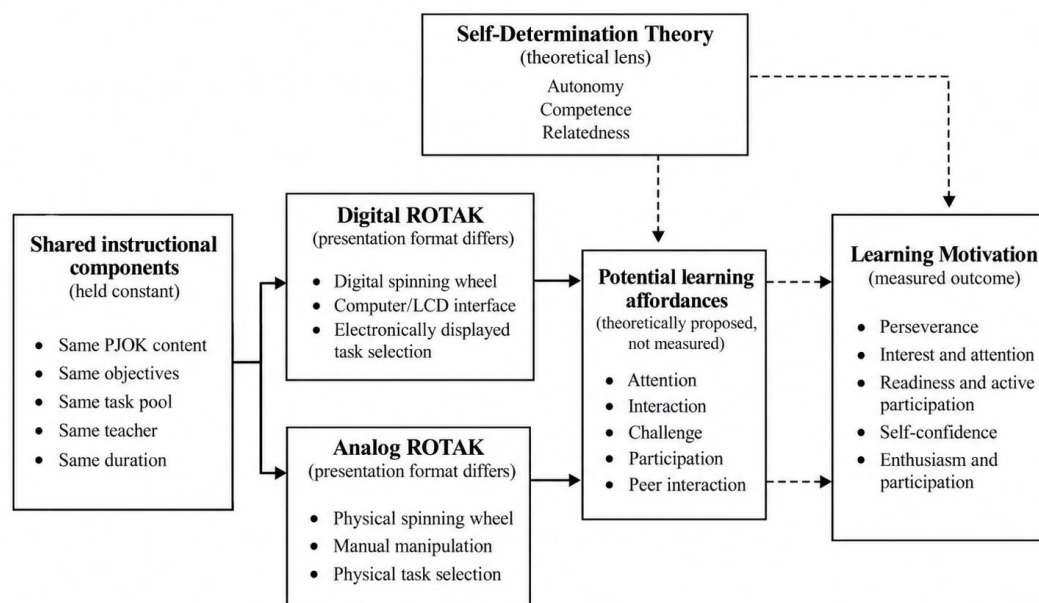
Study	Population/Context	Intervention or Comparison	Main Relevant Finding	Limitation Relative to Present Study
Quintas et al. (2020)	417 primary-school students	Gamified exergaming vs. traditional PE	Positive effects on several psychological outcomes; motivational effects were not uniform	Not a matched digital–analog comparison
Fernández- Río et al. (2022)	54 secondary- school students	Gamified PE vs. traditional instruction	Favorable motivation and basic psychological- need outcomes	Did not compare equivalent digital and physical media
Camacho- Sánchez et al. (2023)	Systematic review of PE studies	Game-based learning and gamification	Generally favorable effects on motivation and engagement	Considerable methodological heterogeneity
Sotos- Martínez et al. (2024)	275 secondary- school students	Gamified vs. control PE instruction	Improved autonomy, competence, relatedness, and intrinsic motivation	Gamification compared with nongamified instruction
Xiang et al. (2025)	Educational setting outside PE	Equivalent digital vs. non-digital educational games	Digital favored intrinsic motivation; non-digital favored knowledge acquisition	Conducted outside Physical Education
Hsia et al. (2025)	University PE	SDT-based gamified intelligent tutoring vs. conventional tutoring	Improved engagement and skill performance	University population and technology- intensive intervention
Sal-de-Rellán et al. (2025)	Systematic review of adolescent PE	Gamification and motivation	Generally positive motivational evidence	Methodological inconsistencies; limited direct media-format evidence

Study	Population/Context	Intervention or Comparison	Main Relevant Finding	Limitation Relative to Present Study
Martín-Rodríguez & Madrigal-Cerezo (2025)	Review of technology-enhanced PE	Digital PE technologies	Potential benefits for motivation and engagement; implementation barriers identified	Broad technology focus
Camacho-Illana et al. (2026)	Rural children and adolescents	Digital technologies for physical activity	Potential benefits alongside infrastructure and equity constraints	Broader physical-activity focus
Present study	62 seventh-grade students in a resource-constrained school	Digital ROTAK vs. Analog ROTAK with matched instructional components	Compares two formats of the same educational spinning-wheel game	Short-duration, nonrandomized two-class design

The conceptual framework is presented in Figure 1. SDT provides the motivational lens, while the two ROTAK formats represent alternative ways of presenting and interacting with the same instructional game. The illustrated digital and analog characteristics are conceptualized as potential affordances rather than measured mediators. The study therefore tests differences in motivational outcomes, not whether any particular visual, feedback, social, or tactile mechanism caused those differences. The framework is also consistent with broader motivational research in education and Physical Education (Chen et al., 2014; Xiong, 2025; Xu et al., 2025; Zha et al., 2025).

The study makes two principal contributions. First, it compares two instructional formats while matching content, learning objectives, teacher, task pool, instructional sequence, duration, and assessment procedures as far as practicable. Second, it contributes evidence from a junior secondary school operating with limited instructional resources, where choices between digital and low-technology game-based media have direct practical relevance. Because the conditions were delivered to two pre-existing classes, however, media format cannot be completely separated from class-level characteristics.

Accordingly, this study aimed to (1) examine the change in students' learning motivation following instruction using Analog ROTAK; (2) examine the change following instruction using Digital ROTAK; and (3) determine whether the magnitude of pretest-posttest change differed between the two groups. The hypotheses were: H1, learning motivation would increase significantly after Analog ROTAK instruction; H2, learning motivation would increase significantly after Digital ROTAK instruction; and H3, the magnitude of change would differ significantly between groups. Because the intervention used nonrandomized intact classes, baseline-adjusted posttest motivation was additionally compared using pretest motivation as a covariate.



The two formats shared instructional content, objectives, teacher, task structure, and duration but differed in presentation format. Potential motivational processes are theoretically informed by Self-Determination Theory and were not tested as mediators.

Solid arrows = implemented design and measured outcome; dashed arrows = theoretical pathways not directly tested.

Figure 1. Conceptual framework for comparing Digital and Analog ROTAK.

METHOD

Research Design

This study employed a quantitative quasi-experimental nonequivalent pretest-posttest comparison-group design. The intervention was implemented in two pre-existing seventh-grade classes, making individual random assignment impractical while preserving the natural instructional setting. Similar pretest-posttest quasi-experimental approaches have been used in educational and Physical Education research (Fernández-Río et al., 2022; Supratman et al., 2025). One intact class received Digital ROTAK instruction and the other received Analog ROTAK instruction. No conventional-instruction or untreated control group was included; therefore, the design compared motivational changes and baseline-adjusted posttest scores between ROTAK formats rather than establishing unrestricted causal effects.

The study design and measurement sequence are summarized in Table 2. Because the classes differed at baseline, the principal between-group comparison adjusted posttest motivation for pretest motivation.

Table 2. Nonequivalent Pretest-Posttest Comparison-Group Design

Group	Pretest	Treatment	Posttest
Digital ROTAK	O ₁	X _D : Digital ROTAK	O ₂
Analog ROTAK	O ₃	X _A : Analog ROTAK	O ₄

Participants and Research Setting

The study was conducted at SMP Satu Atap 4 Gunungsari, West Lombok Regency, West Nusa Tenggara, Indonesia, during the second semester of the 2025/2026 academic year. SMP Satu Atap refers to an Indonesian one-roof school arrangement that provides junior-secondary education within an integrated school setting.

The population consisted of all 62 seventh-grade students enrolled at the school. Because the complete eligible population was included, total population sampling (census sampling) was employed. The sample comprised 31 students in the Digital ROTAK class and 31 students in the Analog ROTAK class. All 62 students completed the pretest and posttest, so no attrition occurred between measurement occasions.

Students belonged to two classes administratively established before the research commenced and were not reassigned between classes. One intact class received Digital ROTAK and the other Analog ROTAK; individual randomization was not performed. Inclusion criteria were: (1) registration as a seventh-grade student at the school, (2) active participation in PJOK lessons, and (3) completion of both pretest and posttest assessments. The sample size was therefore determined by the size of the accessible population rather than by an a priori recruitment target.

ROTAK Learning Media

ROTAK (Roda Putar Edukatif; Educational Spinning Wheel) is a researcher-developed, wheel-based game medium designed to support PJOK instruction. It integrates questions, movement challenges, collaborative activities, decision-making, and game procedures into regular learning activities. The two formats used the same PJOK learning objectives, competency targets, instructional content, task pool, lesson sequence, teacher, instructional duration, and assessment procedures. Their principal difference was the medium through which the spinning wheel and associated learning tasks were presented.

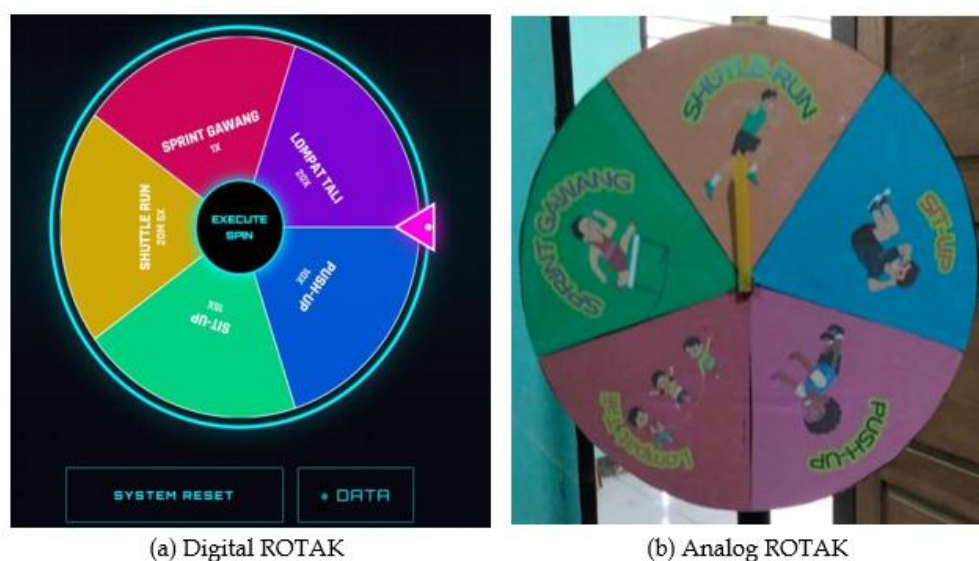


Figure 2. Learning Media Used in the Study: (a) Digital ROTAK and (b) Analog ROTAK

Digital ROTAK used a digital spinning-wheel application displayed through a computer and LCD projector. Students activated the virtual wheel to obtain a randomly selected learning category, question, or movement challenge. Analog ROTAK used a physical spinning wheel constructed from acrylic materials and mounted on a rotating board. Students manually spun the wheel and completed the task corresponding to the selected category. The actual products used during the intervention are shown in Figure 2.

Intervention Procedure and Treatment Equivalence

The intervention was implemented during four PJOK sessions, each lasting 2 × 40 minutes, for 320 minutes of scheduled instruction per group. Each session followed

the same sequence: (1) introduction and apperception, (2) presentation of learning objectives, (3) implementation of the assigned ROTAK format, (4) completion and discussion of selected questions or movement tasks, (5) learning reflection, and (6) lesson closure. The same PJOK teacher taught both groups throughout the intervention to reduce instructor-related variability.

Table 3 summarizes the components that were held constant and those that differed between conditions. The intended instructional contrast was the presentation and interaction format of ROTAK. Because treatment condition coincided with intact-class membership, however, possible class-level differences cannot be completely separated from media-format differences.

Table 3. Equivalence of Digital and Analog ROTAK Instruction

Component	Digital ROTAK	Analog ROTAK
Number of students	31	31
Learning content	Identical	Identical
Learning objectives	Identical	Identical
Competency targets	Identical	Identical
Teacher	Same PJOK teacher	Same PJOK teacher
Number of sessions	4	4
Duration per session	2 × 40 min	2 × 40 min
Lesson sequence	Identical	Identical
Question/movement-task pool	Identical	Identical
Task difficulty	Matched	Matched
Teacher instructions	Standardized	Standardized
Feedback/discussion	Teacher-facilitated	Teacher-facilitated
Assessment procedures	Identical	Identical
Task-selection mechanism	Virtual spinning wheel	Manually operated wheel
Media presentation	Digital interface	Physical wheel
Technological requirement	Computer and LCD projector	Physical ROTAK wheel

Research Instruments

Learning-Motivation Questionnaire

The primary outcome measure was a 20-item learning-motivation questionnaire organized into five content domains: (1) perseverance in learning, (2) interest and attention in PJOK learning, (3) readiness and active participation, (4) self-confidence in performing PJOK tasks, and (5) enthusiasm and participation. Each domain was represented by four items.

The questionnaire used a four-point Likert response format: Strongly Agree, Agree, Disagree, and Strongly Disagree. Positively worded items were scored 4, 3, 2, and 1, respectively. Items 16–20 were negatively worded and reverse-scored 1, 2, 3, and 4. Total scores therefore ranged from 20 to 80, with higher scores indicating stronger learning motivation. The item structure is shown in Table 4.

Examples included “I keep trying to complete PJOK tasks even when they feel difficult” for perseverance, “I pay attention to the teacher's explanation during PJOK lessons” for interest and attention, and “I feel confident when completing tasks or practical activities in PJOK lessons” for self-confidence.

Table 4. Structure and Scoring of the Learning-Motivation Questionnaire

Motivation domain	Positive items	Reverse-scored item	Total items
Perseverance in learning	1, 2, 3	16	4
Interest and attention in PJOK learning	4, 5, 6	17	4
Readiness and active participation	7, 8, 9	18	4
Self-confidence in performing tasks	10, 11, 12	19	4
Enthusiasm and participation	13, 14, 15	20	4
Total	15 positive items	5 reverse-scored items	20

Instrument Validity and Reliability

Before administration, the questionnaire was evaluated through expert judgment involving two experts in Physical Education and educational evaluation. The experts assessed item relevance, alignment with the five intended content domains, clarity of wording, language appropriateness for junior-secondary students, suitability of the response format, and relevance to the PJOK context. Expert judgment used a four-point validation scale. The overall mean validity score was 3.55 out of 4.00, which falls within the 2.8–3.6 “valid” category used by Muhali et al. (2021).

Internal consistency of the 20-item total score was evaluated with Cronbach's alpha (Tavakol & Dennick, 2011). The questionnaire yielded $\alpha = .666$ at pretest and $\alpha = .666$ at posttest, indicating modest internal consistency in the present sample. Because the four-item domain scores showed inadequate internal consistency when examined separately, inferential hypothesis testing was based on the total 20-item score. Domain scores were used only to describe indicator-level patterns.

Classroom Observation and Documentation

A structured classroom observation instrument was used to monitor implementation. The eight aspects were student readiness, student activeness, student enthusiasm, engagement in PJOK activities, response to the ROTAK medium, student cooperation, fidelity of lesson implementation, and classroom atmosphere. Each aspect was rated from 1 (Very Poor) to 4 (Very Good), with space for observer notes.

An eight-item documentation checklist covered the school profile, student list, PJOK timetable, teaching module or lesson plan, Digital and Analog ROTAK materials, photographs, research-permission documentation, and pretest-posttest questionnaire records. Observation and documentation were used as implementation-support evidence rather than primary outcome measures. The PJOK teacher also provided implementation-related feedback, but this information was not treated as a formal qualitative dataset or subjected to thematic analysis. Monitoring implementation is important because variation in lesson delivery can influence intervention outcomes (Rice et al., 2025).

Data Collection Procedure

Before the intervention, students in both classes completed the 20-item learning-motivation questionnaire under the same administration procedures. Each class then completed four regularly scheduled PJOK sessions using its assigned ROTAK format.

Classroom implementation was monitored with the structured observation sheet, including the criterion concerning adherence to planned activities and time allocation. Immediately after the fourth session, the same questionnaire was administered as the posttest. The same scoring procedure, including reverse scoring of Items 16–20, was applied at both measurement occasions.

Ethical Considerations

Before data collection, the research protocol, intervention procedures, participant recruitment process, and data-collection procedures were reviewed and approved by the Ethical Committee of Universitas Muhammadiyah Malang (approval No. E.5./45/DPPs-UMM/I/2026). Official permission to conduct the study was also obtained from the principal of SMP Satu Atap 4 Gunungsari, and the intervention schedule was coordinated with the PJOK teacher to avoid disrupting the school's regular instructional program.

Before the pretest, students received an age-appropriate explanation of the study purpose, instructional activities, questionnaire procedures, and intended academic use of the collected data. Students were informed that participation in data collection was voluntary, that their responses would not affect their PJOK grades, and that individual responses would not be disclosed. Students who agreed to participate and met the inclusion criteria proceeded with the study procedures.

Participant confidentiality was maintained throughout data collection, analysis, and reporting. Student responses were recorded and analyzed using coded identifiers rather than names, and findings were reported only in aggregated form. Access to the study data was restricted to research purposes, and no personally identifying information was included in the statistical analyses or publication.

Data Analysis

All statistical analyses were performed using IBM SPSS Statistics. Positively worded items were scored directly, Items 16–20 were reverse-scored, and the 20 item scores were summed to obtain total motivation scores ranging from 20 to 80. Means and standard deviations were calculated for each group and measurement occasion, and Cronbach's alpha was calculated separately at pretest and posttest.

The Shapiro-Wilk test was used to evaluate normality, and Levene's test was used to assess between-group homogeneity of variance. For ANCOVA, the relationship between the baseline covariate and posttest outcome, normality of residuals, homogeneity of error variance, and homogeneity of regression slopes were evaluated. Homogeneity of regression slopes was examined by testing the Group $\times$ Pretest interaction.

Paired-samples t-tests evaluated pretest-posttest change separately within each group. Mean change, 95% confidence intervals, t statistics, p values, and paired standardized effect sizes (Cohen's dz) were reported. To test H3 directly, individual change scores were calculated as posttest minus pretest and compared between groups. Welch's t-test was used when the equal-variance assumption was not satisfied.

Because the intact classes differed at baseline, the principal endpoint comparison used analysis of covariance (ANCOVA), with posttest motivation as the dependent variable, group as the fixed factor, and pretest motivation as the covariate. Baseline adjustment is preferable to an unadjusted follow-up comparison when initial differences are present (Vickers & Altman, 2001), and ANCOVA has been used in

comparable technology-supported Physical Education research (Hsia et al., 2025). Adjusted means, 95% confidence intervals, F statistics, p values, and partial eta squared (η^2p) were reported. Statistical significance was evaluated at two-tailed $\alpha = .05$. ANCOVA was interpreted as statistical adjustment for observed baseline motivation, not as elimination of all selection bias arising from nonrandomized intact classes.

RESULTS AND DISCUSSION

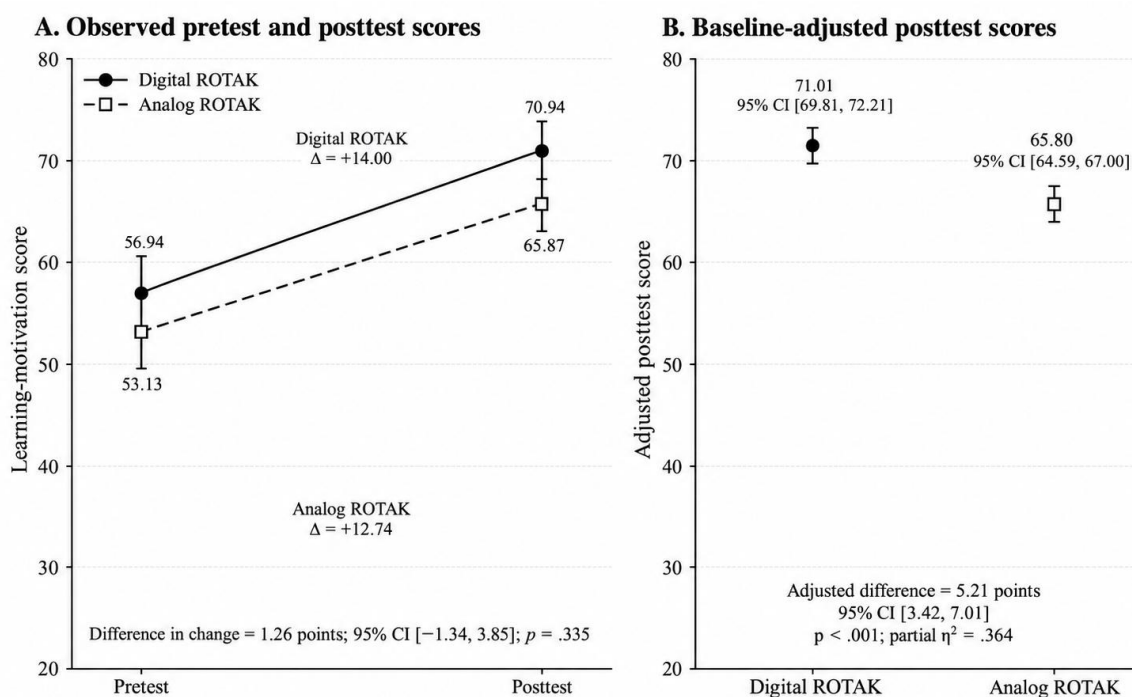
Descriptive Statistics and Baseline Comparison

Descriptive statistics for learning-motivation scores are presented in Table 5. Both groups showed higher mean scores at posttest than at pretest.

Table 5. Descriptive Statistics of Students' Learning-Motivation Scores

Group and Measurement	n	Mean	SD	Minimum	Maximum
Digital ROTAK - Pretest	31	56.94	4.11	48	65
Digital ROTAK - Posttest	31	70.94	3.40	63	76
Analog ROTAK - Pretest	31	53.13	3.61	46	60
Analog ROTAK - Posttest	31	65.87	2.85	58	71

As shown in Table 5, the Digital ROTAK group increased from 56.94 (SD = 4.11) to 70.94 (SD = 3.40), a mean increase of 14.00 points. The Analog ROTAK group increased from 53.13 (SD = 3.61) to 65.87 (SD = 2.85), a mean increase of 12.74 points. The groups were not equivalent at baseline: the Digital group scored 3.81 points higher than the Analog group, $t(60) = 3.88$, $p < .001$, 95% CI [1.84, 5.77], Cohen's $d = 0.98$. This baseline difference confirmed the need for an adjusted endpoint comparison.



Panel A shows observed means with SD error bars. Panel B shows ANCOVA-adjusted posttest means with 95% CI error bars.

Figure 3. Observed and baseline-adjusted learning-motivation scores in the Digital and Analog ROTAK groups.

Figure 3 displays the descriptive pattern relative to the questionnaire's theoretical score range of 20–80. Error bars represent standard deviations. Descriptive increases alone do not establish whether the magnitude of improvement differed statistically between groups.

Statistical Assumption Tests

Normality of pretest and posttest total scores was evaluated with the Shapiro-Wilk test. Table 6 shows that all four tests were nonsignificant, providing no evidence of departure from normality.

Table 6. Shapiro-Wilk Tests of Normality

Group	Measurement	W	p	Decision
Digital ROTAK	Pretest	.990	.990	Normally Distributed
Digital ROTAK	Posttest	.957	.236	Normally Distributed
Analog ROTAK	Pretest	.983	.886	Normally Distributed
Analog ROTAK	Posttest	.972	.569	Normally Distributed

Levene's tests indicated no evidence of unequal variance at pretest, $F = 0.20$, $p = .652$, or posttest, $F = 0.85$, $p = .361$. For ANCOVA, the Group $\times$ Pretest interaction was nonsignificant, $F(1, 58) = 2.60$, $p = .112$, supporting the homogeneity-of-regression-slopes assumption. Residual normality was also acceptable, Shapiro-Wilk $W = .967$, $p = .094$.

Within-Group Changes in Learning Motivation

Paired-samples t -tests were conducted to evaluate pretest-posttest change within each group. Verified results from the final participant-level dataset are presented in Table 7.

Table 7. Paired-Samples t -Test Results for Pretest-Posttest Changes

Group	Pretest Mean $\pm$ SD	Posttest Mean $\pm$ SD	Mean Change	95% CI	t	df	p	Cohen's dz
Digital ROTAK	56.94 $\pm$ 4.11	70.94 $\pm$ 3.40	14.00	11.84–16.16	13.24	30	< .001	2.38
Analog ROTAK	53.13 $\pm$ 3.61	65.87 $\pm$ 2.85	12.74	11.22–14.26	17.11	30	< .001	3.07

As shown in Table 7, motivation increased significantly within the Digital ROTAK group, mean change = 14.00, 95% CI [11.84, 16.16], $t(30) = 13.24$, $p < .001$, $dz = 2.38$, and within the Analog ROTAK group, mean change = 12.74, 95% CI [11.22, 14.26], $t(30) = 17.11$, $p < .001$, $dz = 3.07$. Under conventional Cohen (1988) benchmarks, both standardized changes were large. These within-group tests do not establish that one format produced greater improvement than the other.

Between-Group Comparison of Pretest-Posttest Change

To test H3 directly, individual change scores were compared. Levene's test for change scores was $F = 4.01$, $p = .0498$; therefore, Welch's t -test was used. Table 8 presents the between-group comparison.

Table 8. Between-Group Comparison of Pretest-Posttest Change Scores

Item	Digital Mean Change $\pm$ SD	Analog Mean Change $\pm$ SD	Mean Diff.	95% CI	Welch's t	df	p	Cohen's d
Digital - Analog	14.00 $\pm$ 5.89	12.74 $\pm$ 4.15	1.26	–1.34 to 3.85	0.97	53.89	.335	0.25

The Digital group improved by 1.26 points more than the Analog group descriptively, but the difference was not statistically significant, Welch's $t(53.89) = 0.97$, $p = .335$, 95% CI $[-1.34, 3.85]$, $d = 0.25$. Accordingly, H3 – the hypothesis that the magnitude of change would differ significantly between groups – was not supported.

Baseline-Adjusted Posttest Comparison

ANCOVA was used as the principal baseline-adjusted endpoint comparison. Table 9 presents adjusted posttest means and the ANCOVA tests.

Table 9. ANCOVA of Posttest Learning Motivation Adjusted for Pretest Scores

Panel / Source	Statistic / Group	Value	95% CI / df	p	Partial η^2
A. Adjusted means	Analog ROTAK adjusted mean	65.80	64.59–67.00	—	—
A. Adjusted means	Digital ROTAK adjusted mean	71.01	69.81–72.21	—	—
A. Adjusted means	Adjusted mean difference	5.21	3.42–7.01	—	—
B. ANCOVA tests	Pretest covariate: F	0.13	df = 1, 59	.716	.002
B. ANCOVA tests	Instructional group: F	33.78	df = 1, 59	< .001	.364
B. ANCOVA tests	Error SS	588.020	df = 59	—	—

After adjustment for pretest motivation, the Digital ROTAK group had a higher adjusted posttest mean (71.01, 95% CI [69.81, 72.21]) than the Analog ROTAK group (65.80, 95% CI [64.59, 67.00]). The adjusted mean difference was 5.21 points, 95% CI [3.42, 7.01]. Instructional group was significantly associated with adjusted posttest motivation, $F(1, 59) = 33.78$, $p < .001$, partial $\eta^2 = .364$. The pretest covariate itself was nonsignificant within the model, $F(1, 59) = 0.13$, $p = .716$; this does not imply that the baseline imbalance or other class-level differences were eliminated.

The ANCOVA and change-score test address different questions. ANCOVA indicated a significant baseline-adjusted posttest difference, whereas the direct comparison of improvement did not show a significant difference in the amount of change.

Effect-Size Summary

Table 10 summarizes effect sizes for the principal contrasts. Effect-size metrics are not interchangeable because they quantify different comparisons.

Table 10. Summary of Effect Sizes for Learning-Motivation Analyses

Analysis	Effect-size measure	Value	Conventional interpretation
Digital ROTAK pretest-posttest change	Cohen's d_z	2.38	Large
Analog ROTAK pretest-posttest change	Cohen's d_z	3.07	Large
Between-group difference in change	Cohen's d	0.25	Small
Baseline-adjusted posttest group comparison	Partial η^2	.364	Large

Descriptive Indicator-Level Patterns

Indicator-level means were calculated descriptively for the five questionnaire content domains. Each domain mean ranged theoretically from 1.00 to 4.00. Because the four-item domain scores were not treated as independently validated inferential subscales, no separate hypothesis tests were conducted at the domain level.

Table 11. Descriptive Mean Scores by Learning-Motivation Indicator

Motivation indicator	Digital Pre	Digital Post	Digital Change	Analog Pre	Analog Post	Analog Change
Learning persistence	2.79	3.48	0.69	2.57	3.25	0.68
Interest and attention	2.85	3.56	0.71	2.71	3.27	0.56
Readiness and active participation	2.85	3.55	0.70	2.68	3.31	0.63
Self-confidence	2.91	3.60	0.69	2.65	3.34	0.69
Enthusiasm and participation	2.83	3.54	0.71	2.68	3.31	0.63

As shown in Table 11, all five indicators increased descriptively in both groups. In the Digital ROTAK group, the largest descriptive increases occurred in interest and attention and enthusiasm and participation (both +0.71), followed by readiness and active participation (+0.70). Self-confidence had the highest Digital ROTAK posttest mean (3.60) but not the greatest increase. In the Analog ROTAK group, the largest descriptive change was self-confidence (+0.69).

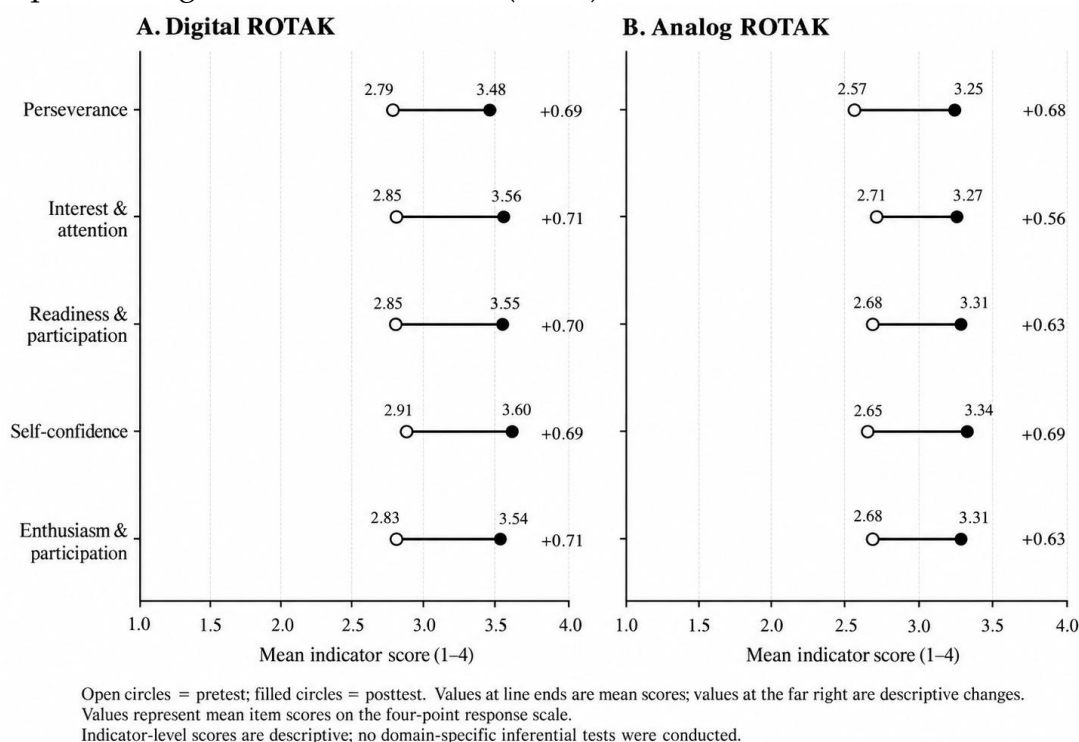
**Figure 4.** Descriptive pretest-posttest changes across the five learning-motivation indicators for Digital and Analog ROTAK.

Figure 4 visually summarizes the indicator means. The Digital group had higher descriptive means than the Analog group at both measurement occasions, but these indicator-level patterns should not be interpreted as evidence of statistically greater effects on individual domains.

Discussion

Overall Changes in Learning Motivation

Three findings are central. First, motivation increased significantly within both ROTAK groups. Second, the magnitude of pretest-posttest change did not differ significantly between groups. Third, Digital ROTAK was associated with a higher posttest motivation score after baseline adjustment. These results indicate substantial

motivational gains during both instructional conditions while distinguishing change over time from the adjusted endpoint comparison.

The within-group increases are consistent with systematic reviews reporting generally favorable associations between game-based or gamified Physical Education and motivation, engagement, enjoyment, and participation (Camacho-Sánchez et al., 2023; Ferriz-Valero et al., 2023; Sal-de-Rellán et al., 2025). Fernández-Río et al. (2020) likewise reported increased intrinsic motivation and meaningful experiences characterized by enjoyment, social interaction, challenge, and learning. However, the present study had no conventional-instruction control group; repeated measurement, teacher influence, novelty, or other time-related influences cannot therefore be separated completely from the observed pretest-posttest increases.

Digital and Analog ROTAK: Change Scores and Adjusted Posttest Differences

The direct comparison of change did not support H3. Digital ROTAK increased by 14.00 points and Analog ROTAK by 12.74 points, but the 1.26-point difference was nonsignificant and small in standardized terms. By contrast, ANCOVA showed a 5.21-point adjusted posttest difference favoring Digital ROTAK. These analyses answer different questions: the change-score test evaluates whether one group improved more, while ANCOVA compares posttest levels conditional on baseline.

This distinction is especially important because the intact classes were nonequivalent at baseline. ANCOVA adjusts statistically for measured baseline motivation, but it does not eliminate selection bias or unmeasured class-level differences. The higher adjusted posttest score should therefore be interpreted as a baseline-adjusted group difference rather than definitive proof that the digital presentation format caused superior improvement.

Interpretation Through Self-Determination Theory

SDT provides a useful interpretive framework for understanding why game-based instruction may support motivation. Learning environments can be motivationally supportive when they offer meaningful choice, appropriately challenging tasks, opportunities to experience competence, and positive social interaction. School-based gamification studies have reported improvements in autonomy, competence, relatedness, and intrinsic motivation (Fernández-Río et al., 2022; Sotos-Martínez et al., 2024), and SDT-based gamified intelligent tutoring has also been associated with stronger engagement (Hsia et al., 2025).

These mechanisms were not measured directly in the present study. Autonomy, competence, and relatedness should therefore be treated as plausible theoretical processes rather than demonstrated mediators. The five questionnaire domains describe the content of the learning-motivation instrument and are not substitutes for validated SDT need-satisfaction scales.

Interpretation of the Baseline-Adjusted Digital ROTAK Difference

The higher baseline-adjusted posttest score in the Digital group is compatible with literature suggesting that technology-enhanced Physical Education can support motivation and engagement through interactive presentation, feedback, personalization, and gamified learning opportunities (Goodyear et al., 2023; Martín-Rodríguez & Madrigal-Cerezo, 2025). Digital literacy and teacher readiness are also relevant because technology is beneficial only when integrated pedagogically rather than used as a substitute for instruction (Adi et al., 2023; Elbadiansyah et al., 2025; Mackenbrock & Kleinert, 2026).

The broader literature cited in the original manuscript similarly illustrates the diversity of conditions shaping technology-supported PJOK: teacher professionalism and rural readiness (Aras et al., 2025), e-modules and teacher creativity (Fantiro et al., 2025), video-supported teaching practices (Julyanto et al., 2026), audiovisual media (Silaban et al., 2025), and digital learning for students with special needs (Rufi'i et al., 2026). Widiatmoko and Wibowo (2026) also emphasize the relationship between learning motivation and perceived PJOK effectiveness. These studies support attention to implementation context, not an assumption that technology itself guarantees superior outcomes.

In the present study, visual interactivity, electronic task selection, and rapid display of activities are plausible explanations for the adjusted Digital ROTAK difference, but these features were not manipulated or measured independently. Claims about immediate feedback, novelty, or visual stimulation must therefore remain interpretive rather than causal.

Educational Value of Analog ROTAK

Analog ROTAK also showed a large within-group increase, and the direct change comparison did not establish a significant advantage for Digital ROTAK. This finding argues against treating the physical format as an ineffective or intrinsically inferior alternative. Non-digital games can support challenge, direct manipulation, peer interaction, and participation without requiring sophisticated infrastructure. Schmidthaler et al. (2023) demonstrated that non-digital game-based activity can support engagement and collaboration in secondary-school contexts, while Mustara et al. (2025) documented the feasibility of low-cost traditional-game instruction.

Analog ROTAK may therefore be especially relevant where computers, projection facilities, technical support, or stable digital infrastructure are limited. This contextual perspective also aligns with literature on physical literacy and active participation (Handryant et al., 2026) and reviews emphasizing that effective PJOK methods depend on pedagogical fit rather than technology alone (Murjani & Mashud, 2025).

Indicator-Level Patterns

Descriptive indicator-level scores increased across all five domains in both groups. In Digital ROTAK, the largest descriptive increases occurred in interest and attention and in enthusiasm and participation; self-confidence had the highest posttest mean but did not show the largest increase. In Analog ROTAK, self-confidence showed the largest descriptive increase.

These patterns are broadly compatible with research indicating that game-based Physical Education can support engagement and motivation-related experiences (Sotos-Martínez et al., 2024; Wahyuniati et al., 2025). Nevertheless, separate baseline-adjusted inferential tests were not conducted for the five domains, and their short subscales did not show sufficient reliability for strong inferential claims. The domain patterns should therefore remain descriptive.

Findings in Relation to Mixed Evidence in the Literature

Although much of the literature reports favorable motivational outcomes, effects are not uniform. Quintas et al. (2020) observed positive effects of gamified exergaming on several psychological outcomes but not all motivational contrasts. Sevilla-Sanchez et al. (2023) found improved motor learning without corresponding improvement in motivation, and Tudela-Petit et al. (2026) reported selective rather than generalized

motivational effects. These findings suggest that outcomes depend on intervention design, duration, population, game elements, comparison condition, and measurement strategy.

Physical Education studies also target outcomes beyond motivation. For example, Nenot'ek et al. (2026) examined physical-fitness responses in junior high students, while Mustara et al. (2025) focused on fundamental motor skills. Such work reinforces the need for future ROTAK studies to include objective movement, fitness, and learning outcomes rather than relying on motivation alone.

Practical Implications

Digital ROTAK may be useful when computers and projection facilities are consistently available, while Analog ROTAK provides a lower-technology alternative that can preserve the same content, task pool, and game structure. Because the change-score comparison was nonsignificant, media selection should be guided by pedagogical objectives, teacher competence, classroom organization, and available infrastructure rather than by an assumption that digital media always produce greater motivational gains.

Schools should also consider teacher readiness and contextual support. Research on rural implementation and curriculum change emphasizes that infrastructure, professional learning, and local conditions shape teachers' capacity to implement innovative approaches (Aras et al., 2025; Camacho-Illana et al., 2026; Dartini et al., 2026).

Limitations and Directions for Future Research

Several limitations constrain interpretation. First, the sample consisted of 62 students from two intact classes in a single school. Because instructional condition and class membership coincided, media-format effects cannot be completely separated from class-level characteristics. Second, individual random assignment was not performed and the groups differed significantly at baseline. ANCOVA adjusted for observed baseline motivation but could not eliminate unmeasured confounding. Third, the absence of a conventional-instruction control group prevents attribution of all within-group improvement specifically to ROTAK.

Fourth, the intervention lasted only four sessions, so persistence of motivational changes is unknown. Fifth, the primary outcome was self-reported, and the total questionnaire showed modest internal consistency ($\alpha = .666$ at both measurement occasions). Domain scores were not sufficiently reliable for strong domain-level inference. Sixth, implementation fidelity was monitored structurally but was not modeled quantitatively. Finally, digital familiarity, socioeconomic access to technology, and preference for digital or physical games were not included as moderators.

Future studies should use larger multi-school samples, longer interventions, follow-up measurement, stronger fidelity reporting, and randomized or cluster-randomized designs where feasible. A conventional-instruction comparison group would clarify whether ROTAK produces gains beyond normal instruction. Mixed-method approaches and broader outcomes—including motor competence, cognitive learning, physical activity, enjoyment, and behavioral engagement—would provide a more complete evaluation.

Taken together, the results indicate that motivation increased substantially during both Digital and Analog ROTAK instruction. The amount of pretest-posttest

improvement did not differ significantly between groups, whereas Digital ROTAK was associated with a higher posttest score after baseline adjustment. Both formats can therefore be considered feasible game-based instructional options, with selection guided by pedagogical purpose and contextual feasibility rather than technological sophistication alone.

CONCLUSIONS

This study found that students' learning motivation increased significantly from pretest to posttest in both the Digital ROTAK and Analog ROTAK groups. However, the magnitude of improvement did not differ significantly between the two groups, indicating that neither format produced a statistically greater pretest-to-posttest gain during the four-session intervention. After adjustment for baseline motivation, the Digital ROTAK group showed a significantly higher posttest motivation score than the Analog ROTAK group. Thus, the principal finding is not that Digital ROTAK generated greater motivational improvement, but that it was associated with a higher baseline-adjusted level of motivation at the end of the intervention.

The study contributes empirical evidence by comparing digital and physical versions of the same wheel-based educational game while maintaining equivalent instructional content, learning objectives, task structure, teacher, and instructional duration. The findings indicate that both ROTAK formats are feasible game-based options for PJOK instruction and that the format of media presentation may be relevant to students' motivational outcomes. However, because the study used two nonrandomized intact classes from a single school, included no conventional-instruction control group, and implemented the intervention for only four sessions, the findings should be interpreted as context-specific evidence rather than definitive evidence of the causal superiority of either format.

Overall, Digital and Analog ROTAK provide two adaptable approaches for incorporating game-based learning into junior-secondary PJOK. Their educational value should be considered in relation to instructional objectives, classroom conditions, available resources, and the quality of implementation.

RECOMMENDATIONS

PJOK teachers may use ROTAK as an alternative game-based instructional medium when its tasks and game procedures are aligned with the intended learning objectives. Digital ROTAK may be selected in classrooms with reliable access to computers and projection facilities, whereas Analog ROTAK provides a practical alternative when technological resources are limited. Because the present study did not demonstrate a significant difference in the magnitude of motivational improvement between the two formats, media selection should be based on pedagogical suitability and available school resources rather than an assumption that the digital format is inherently more effective.

Schools implementing ROTAK should support consistent instructional delivery by providing appropriate facilities, sufficient preparation time, and opportunities for teachers to adapt game-based activities to curriculum requirements. Where digital media are used, technical readiness should be considered alongside pedagogical preparation; where Analog ROTAK is used, the physical materials and task organization should be maintained so that all students have adequate opportunities to participate.

Future research should test Digital and Analog ROTAK in larger and more diverse samples, across multiple schools and over longer intervention periods. Randomized or cluster-randomized designs and the inclusion of a conventional-instruction comparison group would provide stronger evidence regarding the relative effects of the two formats. Follow-up measurements are also needed to determine whether motivational changes are sustained beyond the immediate intervention period. Further studies should examine additional outcomes, including motor competence, cognitive learning, physical activity, enjoyment, and behavioral engagement, and should use well-validated measurement instruments together with systematic treatment-fidelity assessment. Mixed-method studies incorporating structured student interviews, teacher reflections, and classroom observations may further clarify how students experience the distinctive features of Digital and Analog ROTAK.

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Conflict of Interest Statement

The authors declare no conflict of interest.

Informed Consent

Participants received an age-appropriate explanation of the study and agreed to participate in data collection under school authorization; confidentiality and voluntary participation procedures are described in the Method.

Data Availability

The data that support the findings of this study are available from the corresponding author, Erna Yayuk, upon reasonable request.

Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Junaidi	✓	✓	✓	✓	✓	✓		✓	✓	✓				✓
Erna Yayuk	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓		
Budiono	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓		

C : Conceptualization

M : Methodology

So : Software

Va : Validation

Fo : Formal analysis

I : Investigation

R : Resources

D : Data Curation

O : Writing - Original Draft

E : Writing - Review & Editing

Vi : Visualization

Su : Supervision

P : Project administration

Fu : Funding acquisition

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