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Effectiveness of Mastery Learning Model Assisted by Table Tennis Ball Launcher in Improving Table Tennis Basic Skills Among Students in Cimahi

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Abstract: Table tennis is one of the compulsory sports in the Indonesian physical education curriculum, yet empirical evidence on effective instructional models for this discipline remains limited, particularly in the Cimahi region of West Java. Low student mastery rates in table tennis basic skills necessitate innovative pedagogical interventions that can systematically improve outcomes. Objective: This study aimed to determine the effectiveness of the Mastery Learning model assisted by a table tennis ball launcher in improving students' table tennis basic skills, assessed against a minimum mastery criterion of 80% student completion. Methods: A one-group pretest-posttest design was employed with 50 students (30 male, 20 female) from SMP Negeri 3 Cimahi, West Java, Indonesia, selected through purposive sampling. The intervention consisted of eight weeks of Mastery Learning instruction assisted by a table tennis ball launcher (Newgy Robo-Pong). Pre-test and post-test data were collected using a standardized table tennis basic skills test (forehand, backhand, and service). Data were analyzed using a paired-samples t-test and N-Gain score analysis. Results: Post-test scores ($M = 82.84$, $SD = 6.53$) were significantly higher than pre-test scores ($M = 63.22$, $SD = 9.12$), $t(49) = 13.84$, $p < 0.001$. The N-Gain score was 0.54 (moderate category). Forty-three of 50 students (86%) achieved mastery, exceeding the 80% criterion. Conclusion: The Mastery Learning model assisted by a table tennis ball launcher significantly improved students' basic table tennis skills and effectively met the minimum mastery standard. These findings suggest that technology-assisted mastery learning is a viable and effective approach for physical education in Indonesian schools.

Keywords: Mastery Learning; Table Tennis; Ball Launcher; Physical Education; Student Achievement; Cimahi.

▪ INTRODUCTION

Physical education plays an important role in the overall development of students including the development of physical fitness, psychomotor skills, knowledge of sports, and social skills. The Indonesian Independent Curriculum states that table tennis is a mandatory sport in the field of physical education, sports, and health (PJOK) for junior high and high school students. The Independent Curriculum states that table tennis is a mandatory sport in the field of physical education, sports, and health (PJOK) for elementary and high school students (Muhadi, Muhammad, and Kogoya 2024).

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The importance of table tennis in the curriculum is undeniable, yet empirical data from schools in the Cimahi area, West Java consistently shows that a significant number of students do not achieve the minimum level of proficiency in basic table tennis skills, such as forehand strokes, backhand strokes, and serving techniques (Simanjuntak and Nurhayati 2024)This scenario highlights the systemic gap between curriculum expectations and actual learning outcomes, underscoring the need for evidence-based pedagogical interventions. The teaching philosophy developed by Bloom and refined through decades of empirical research, is based on the belief that almost all students can achieve high levels of competence if given sufficient instruction, time, and corrective feedback (Yasin et al. 2025). Failure is not seen as a deficiency in the student but as a signal to revise instruction, requiring cyclical assessment, enrichment, and corrective instruction (DellAntonio 2026). Education can benefit from a systematic approach to ML to strengthen basic motor skills before introducing higher-level skills, thereby encouraging progressive skill development and reducing the buildup of unresolved learning deficits (Pellas 2026), (Cohen, Martin, and Ziegler 2024). In Indonesian schools, the empirical application of machine learning (ML) in physical education, Physical Education, in the context of specific sports such as table tennis, is still under-recognized. The educational environment in general has reported significant improvements in student achievement, but the integration of technology-assisted practice tools within an ML framework is a research gap that this study aims to address (Kober, Oztop, and Peters 2011),(Robin et al. 2023). In particular, there is no published research on the synergistic effects of a table tennis ball launcher with a mastery-based learning model for high school students in Indonesia.

Table tennis ball launchers (TTBLs), also known as multiball training devices or robots, are motorized devices that launch table tennis balls with programmable speed, spin rate, and trajectory (Ardianto et al. 2023). They have been shown to facilitate massed and distributed practice with high ecological validity, allowing students to perform more repetitions of quality practice per unit time compared to using only a human partner (Safari and Saptani 2019),(Ardianto et al. 2023). Found that novice students trained with an automated launcher demonstrated significantly better forehand and backhand stroke consistency compared to those trained with conventional peer-partner methods. These findings were further supported in a meta-analysis, which found a pooled effect size of $d = 0.74$ for ball machines compared to control conditions across racquet sports. The findings suggest that TTBLs are more than just tools; they are substantive pedagogical resources that can accelerate skill acquisition (Assiddiq, Ayi Suherman, and Indra Safari 2023). A preliminary field survey was done before this study at SMP Negeri 3 Cimahi, Cimahi, West Java, and showed that the percentage of Grade VIII students who achieved the minimum completion score (Kriteria Ketuntasan Minimal / KKM) of 75 for table tennis assessment in the 2023/2024 academic year was below 55%. Teachers identified this deficit due to a lack of opportunities for individual practice, varied skill levels at entry, and no systematic mechanisms for corrective feedback. These field observations are consistent with the wider findings (Febrianto et al. 2023). Reported that Indonesian PE classes often do not have structured formative assessment cycles, relating to physical education underachievement in West Java secondary schools (Sunaryo 2017).

This problem needs to be addressed urgently, further accentuated by the developmental implications of poor motor skill proficiency (Oñate Navarrete, Batalla Flores, and Paez Herrera 2020). reported that adolescents with poor fundamental movement skills are significantly less likely to maintain active lifestyles during adulthood contributing to increased sedentary behaviour and the risk of non communicable disease. Moreover, sport skill competence in physical education has been associated to intrinsic motivation, self-efficacy and peer social integration (Arteaga-Ponce and Castro-Valdiviezo 2024). Therefore, the mastery of table tennis skills is not just an academic requirement, but a matter of student health and wellbeing in the long run.

Previous studies of instructional models in physical education have focused mainly on cooperative learning, sport education, and direct instruction models (Legrain et al. 2021). Demonstrated the value of criterion-referenced assessment in sport education, and highlighted the role of formative feedback in enhancing PE outcomes, the synthesis of criterion based mastery standards with automated practice technology as suggested herein represents a methodological novelty (Gao 2025). Noted that technological feedback mechanisms available in racket sports offer a condition of accelerated neural encoding of motor patterns through increased frequency and immediacy of feedback. This mechanism would theoretically be consistent with the corrective feedback cycles required by the ML model (Chen 2022). Not use any technology-assisted delivery system, but noted substantial improvements in motor skill performance when ML was used in a structured sport environment.

This study is therefore novel in the sense that incorporates the ML instructional model into the ball launcher device. This study applies the ML instructional model to the context of Indonesian secondary school table tennis. This combination leverages the theoretically sound ML structure with its diagnostic pretests, corrective cycles, and mastery confirmation posttests, and adds the high repetition, self paced practice affordances of the TTBL (Deng, Soachalerm, and Tasnaina 2024). motor learning is optimised when practice conditions combine specificity of task demands with sufficient volume of deliberate repetition which are precisely met by this combined intervention. The research gap is thus the absence of empirical evidence on whether this technology-augmented ML approach can help 80% or more students attain minimum competency in table tennis basic skills. Further motivation for this study is the strategic agenda of the Indonesian Ministry of Education to integrate digital and technology resources in classroom instruction as part of the Merdeka Belajar reforms (Gustiawati et al. 2024). didn't. In a similar context demonstrated that structured training programmes that are rich in repetitions bring about statistically significant improvements in table tennis skills of junior high school students in Java (Nopembri et al. 2022). Compared outcome-based education frameworks with mastery learning in theory and found that the latter produces more sustainable and equitable learning outcomes when implemented with fidelit (Nopembri et al. 2022). Reviewed evidence from 34 studies in Indonesian PE and found that innovative models outperform traditional direct instruction in measurable skill improvement.

Thus, the purpose of this study is to answer the following research questions: (1) Is there any significant difference between pre-test and post-test scores on basic skills of table tennis after Mastery Learning model assisted by ball launcher? (2) Is the intervention effective in reaching at least 80% of the students to the minimum mastery criterion? The research objective is to know the effectiveness of the Mastery Learning model assisted by a table tennis ball launcher in increasing the basic skills of table tennis on Grade VIII students of SMP Negeri 3 Cimahi, West Java, Indonesia.

▪ METHOD

Research Design

The research was conducted with a pre-experimental design, namely a one-group pretest-posttest design (O_1 X O_2). In this design O_1 is the pre-test measurement, X is the Mastery Learning intervention assisted by a table tennis ball launcher, and O_2 is the post test measurement. This design was selected as appropriate for measurement of within group change due to a particular instructional treatment in a naturalistic school setting. It is an accepted limitation that there is no separate control group, but the design is consistent with established practice in applied physical education research where random assignment to control conditions is ethically or logistically infeasible (Whiston et al. 2024). Written informed consent was obtained from the student guardians, school administration granted permission, and the research followed the research ethics guidelines of Sekolah Tinggi Keguruan Dan Ilmu Pendidikan Pasundan.

Population and Sample

The study population was all students of grade VIII SMP Negeri 3 Cimahi Cimahiutara Sub-district, Cimahi City, West Java Province, Indonesia. SMP Negeri 3 Cimahi is a state junior high school located at Jl. Pesantren No. 3, Cimahi Utara. There were 180 Grade VIII students in all (VIII-A to VIII-F), representing six parallel classes. The study sample was chosen by means of a purposive sampling technique, in which one complete class (Class VIII-C) was selected, with a sample of 50 students (30 male, 20 female; mean age=13.7±0.5 years). Inclusion criteria were students who: (1) were enrolled as active Grade VIII students; (2) had no physical or medical conditions that would prevent participation in table tennis; and (3) had no prior formal table tennis training outside the school curriculum. Exclusion criteria were defined as absences from more than three intervention sessions. All 50 students completed both pre-test and post-test measures, since none of the students were excluded based on these criteria.

Intervention Protocol

The Mastery Learning intervention took place over an 8-week period, with 16 instructional periods of 80 minutes (two sessions per week). The ML cycle consisted of five phases according to Bloom's model as operationalised (Cundiff et al. 2020). (1) Orientation introduction of learning objectives and mastery criteria. (2) Initial Teaching direct instruction and demonstration of table tennis skills (forehand drive, backhand drive, flat serve). (3) Short skill checks at the end of each two-session cycle for Formative Assessment; (4) Corrective Instruction provided remediation for students who did not meet 75% accuracy on formative checks through differentiated drills with the ball launcher set to modified settings; and (5) Enrichment Activities progressed drills and game play for students who demonstrated mastery at each checkpoint.

The table tennis ball launcher (Newgy Robo-Pong 2050) was programmed to launch balls at three difficulty levels: level 1 (2 m/s, no spin, center of table) for initial skill acquisition; level 2 (3.5 m/s, slight topspin, varied direction) for intermediate practice; and level 3 (5 m/s, moderate topspin/backspin, wide-angle variation) for enrichment. The launcher provided a minimum of 50 ball feeds to each student in each practice session, a volume far greater than could be provided in typical peer-partner practice. The instructor used a 15-point behavioural observation checklist to supervise student technique and provided verbal corrective feedback after each set of 10 balls.

Research Resources

The main instrument was a standardised Table Tennis Basic Skills Test (TTBST) that was validated by Ramdani et al. [33] for Indonesian secondary school PE setting. The TTBST measures three skill components: (1) Forehand Drive Accuracy Test (maximum score: 40 points), (2) Backhand Drive Accuracy Test (maximum score: 40 points), and (3) Flat Service Test (maximum score: 20 points). The composite score varies from 0 to 100. The content validity was determined through expert panel review (CVI = 0.91) and the criterion validity was validated with an expert rated observation rubric ($r = 0.87$, $p < 0.001$). The test-retest reliability was $r = 0.89$ (ICC = 0.88; 95% CI [0.82, 0.93]). Based on the school's standard for competency, the minimum mastery score (KKM) was 75 (which means 75 out of 100). The operational success criteria for the intervention were defined as ≥ 80% of students scoring ≥ 75 on the post-test.

Data Analysis

Descriptive statistics (means, standard deviations, minimum and maximum) were calculated for the pre-test and post-test scores. The normality of the data was checked using the Shapiro-Wilk test (appropriate for $n \leq 50$). Both distributions were normally distributed, and a paired-samples t-test was used to evaluate whether the mean difference between pre-test and post-test scores was statistically significant (two-tailed,

α = 0.05). The normalised gain (N-Gain) score formula was employed to determine the magnitude of learning gain: N-Gain = (Post-test Mean − Pre-test Mean) / (Maximum Score Pre-test Mean), with categories of high (≥0.70), moderate (0.30–0.69), and low (<0.30) [24]. The percentage of students achieving mastery (score ≥75) at pre-test and post-test was calculated and compared to the 80% operational standard. The effect size was calculated using Cohen's d. All analyses were conducted using IBM SPSS Statistics version 26.0.

▪ RESULT AND DISCUSSION

Descriptive Statistics

Table 1 presents the descriptive statistics for pre-test and post-test scores on the Table Tennis Basic Skills Test across the three skill components and the composite score.

Table 1. Descriptive Statistics of Pre-test and Post-test Scores (N = 50)

Skill Component	PreMean	Pre SD	Post Mean	Post SD	Min Pre	Max Post
Forehand Drive	25.46	4.12	34.22	2.87	16	39
Backhand Drive	24.80	3.95	33.64	3.11	15	40
Service	12.96	2.44	14.98	1.65	8	20
Composite Score	63.22	9.12	82.84	6.53	45	97

Note: Pre = Pre-test; Post = Post-test; SD = Standard Deviation; Max Score: Forehand = 40, Backhand = 40, Service = 20, Composite = 100.

Normality Test

Prior to inferential analysis, data normality was assessed using the Shapiro-Wilk test. Results are presented in Table 2. Both pre-test (W = 0.965, p = 0.146) and post-test (W = 0.972, p = 0.253) scores satisfied the assumption of normality (p > 0.05), justifying the use of a parametric paired-samples t-test.

Table 2. Shapiro Wilk Normality Test Results

Measurement	Shapiro-Wilk (W)	df	Sig. (p)
Pre-test	0.965	50	0.146
Post-test	0.972	50	0.253

Note: Data are normally distributed at p > 0.05.

Paired-Samples t-Test and Effect Size

A paired-samples t-test was conducted to compare pre-test and post-test composite scores. Results revealed a statistically significant mean improvement of 19.62 points (95% CI [16.81, 22.43]), t(49) = 13.84, p < 0.001 (two-tailed). The effect size was large (Cohen's d = 1.96), indicating a substantial practical significance of the intervention. Table 3 presents the full t-test output.

Normalized Gain (N-Gain) Score

The N-Gain score was calculated as (82.84 − 63.22) / (100 − 63.22) = 19.62 / 36.78 = 0.534, placing the result in the moderate improvement category (0.30 ≤ N-Gain < 0.70). This indicates that the intervention produced a meaningful, albeit moderate, proportion of the theoretically possible improvement given students' entry performance levels.

Frequency Distribution of Pre-test and Post-test Scores

Table 3 presents the frequency distribution of composite scores across defined score intervals for pre-test and post-test measurements, illustrating the shift in score distribution following the intervention.

Table 3. Frequency Distribution of Composite Scores: Pre-test and Post-test (N = 50)

Score Interval	Category	Pre-test f	Pre-test %	Post-test f	Post-test %
40–49	Very Low	5	10.0%	0	0.0%
50–59	Low	8	16.0%	0	0.0%
60–69	Below Mastery	17	34.0%	4	8.0%
70–74	Near Mastery	15	30.0%	3	6.0%
75–84	Mastery	5	10.0%	22	44.0%
85–94	High Mastery	0	0.0%	18	36.0%
95–100	Excellent	0	0.0%	3	6.0%
Total		50	100%	50	100%

Note: Mastery threshold (KKM) = 75. f = frequency.

Student Mastery Achievement

Table 4 summarizes the number and proportion of students achieving mastery (score ≥ 75) at pre-test and post-test, along with the comparison against the 80% operational success criterion.

Table 4. Student Mastery Achievement: Pre-test vs. Post-test vs. 80% Criterion

Category	Pre-test n	Pre-test %	Post-test n	Post-test %
Mastery (≥ 75)	5	10.0%	43	86.0%
Not Mastery (< 75)	45	90.0%	7	14.0%
Total	50	100%	50	100%
80% Criterion Met?	-	No (10%)	-	YES (86%)

Table 4 shows that only 5 students (10%) achieved mastery in pre-test and the rest of the students (90%) did not achieve mastery. Post-test results demonstrated that 43 students (86%) achieved mastery following the eight week Mastery Learning intervention, surpassing the 80% operational criterion by 6 percentage points. Only 7 students (14%) remained below the mastery threshold. In addition, analysis revealed that this group presented attendance irregularities or motor coordination difficulties that required individualised support not included in the current intervention.

DISCUSSION

The main result of this study that the Mastery Learning model assisted by a table tennis ball launcher led to a statistically significant and practically large improvement in students' table tennis basic skills ($t(49) = 13.84$, $p < 0.001$, $d = 1.96$), with 86% of students reaching the minimum mastery standard, is both theoretically coherent and empirically consistent with the extant literature. The findings are discussed in the context of mastery learning theory, motor learning science, and technology-enhanced physical education research.

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The theoretical bases of mastery learning as developed by Bloom and critically assessed argue that if instruction is properly adapted to student needs and if feedback is timely and accurate, then the gaps in the distribution of student achievement typical of traditional instruction can be substantially reduced (Falardeau et al. 2022). The data were fully consistent with this prediction: the pre-test composite scores ranged from 45 to 78 (range = 33 points) whereas the post-test scores ranged from 68 to 97 (range = 29 points) with the entire distribution shifted upward and compressed at the bottom significantly. Such a pattern of compression is precisely what mastery learning theory predicts to be a hallmark of effective corrective feedback interventions (effect sizes ranged from d = 0.70 to 1.20 across their meta-analytic sample) (Joan Casademont, Gagné, and Viladrich Castellanas 2022). as identified by Hattie and Timperley (Turcotte and Mercure 2007). The observed effect size (d = 1.96) is larger than typical benchmarks for educational interventions and is similar to effect sizes reported in similar mastery learning studies in sport contexts d = 1.31 for mastery learning in badminton skills among Indonesian junior high school students was reporte (Gillies 2019). Mastery learning in volleyball was reported with d = 1.58. The larger effect size in the present study may be explained by the additive contribution of the ball launcher which allowed students to accumulate much more volume of deliberate practice than is possible with peer-partner designs (Cuzzolino, Grotzer, and Xu 2023). Established that motor learning is a function of practice quality and quantity; the Newgy Robo Pong 2050 provided an average of 50 quality ball feeds per student per session, or approximately 800 practice repetitions per student across the interventiona volume not possible in traditional PE class formats (Wisniewski, Zierer, and Hattie 2020).

Special attention should be paid to the use of table tennis ball launchers as a pedagogical tool. Of table tennis ball launchers as a pedagogical tool. Note: the use of table tennis ball launchers as a teaching tool (Aulton et al. 2025). Conducted a meta-analysis of 18 automated ball machine studies in racket sports and reported an overall effect size of d = 0.74. The improvement was attributed to three mechanisms: (1) increased training volume, (2) stimulus consistency allowing for accurate error detection, and (3) reduced cognitive load associated with partner coordination, freeing up attentional resources for skill-focused processing (Krizkova, Tomaskova, and Tirkolaee 2021). Participants trained with TTBL had better skill retention at 6-week follow-up compared to peer partner participants (d = 0.61), indicating that skill encoding due to machine training was more durable(Bacovic 2019). 6-week follow-up compared to peer partner participants (d = 0.61), indicating that skill encoding due to machine training was more durable (International Council for Coaching Excellence (ICCE) 14th Global Coach Conference 2023). Protocol, they found that systematic variations in ball delivery parameters, similar to the three-level progression used in this study, optimize the development of adaptive motor programs .ball delivery parameters, similar to the three-level progression used in this study, optimize the development of adaptive motor programs. Currently, a meta-analysis of 18 studies on automated ball machines in racquet sports has been conducted. The combined effect size was d = 0.74. Three mechanisms were found to contribute to the improvement: (1) increased training volume, (2) stimulus consistency that facilitated accurate error detection, and (3) reduced cognitive load from partner coordination, which allowed more attentional resources to be dedicated to skill-focused processing.

Intervention The ML intervention may be enhanced by the formative assessment cycle, which is an important mechanism for improvement beyond that produced by practice volume alone. It is likely that this is enhanced by the formative assessment cycle, which is an important mechanism for improvement beyond that produced by practice volume alone. The use of an integrated practice cycle in the ML intervention is likely an important mechanism for improvement beyond that produced by practice volume alone. They reported significantly higher motor skill scores for advanced students from criterion-based assessment with clear mastery standards compared to a

norm-based approach, which they attributed to the motivational clarity of the stated success thresholds. Motor skill scores from criterion-based assessment with clear mastery standards were higher than from a norm-based approach, which they attributed to the motivational clarity of the stated success thresholds (Müller et al. 2024). Also found that assessment with clear mastery standards resulted in significantly higher motor skill scores for students than a norm-referenced approach. They attributed this effect to the motivational clarity of the stated success thresholds. The results showed significantly higher student motor skill scores compared to the norm-based approach. They attributed this effect to the motivational clarity of the stated success threshold (Ghorbel et al. 2025). found that frequent formative assessment in physical education increased student achievement by 0.48 standard deviations compared to the summative assessment-only condition. In physical education, students achieved 0.48 standard deviations higher than the summative assessment-only condition. In physical education, students achieved 0.48 standard deviations higher than the summative assessment-only condition. The students in this study took formative skills tests every two sessions and received corrective instruction based on their performance profiles. The corrective instruction cycle is a hallmark of ML and ensures that basic skills are consolidated before advanced exercises are introduced. Without this cycle, unresolved skill deficits can accumulate and this is characteristic of less structured teaching approaches (Greenstein 2018; Liu et al. 2025).

Motivation and engagement may be mediating variables.students between ML TTBL interventionbetween ML TTBL intervention and achievement outcomes(Hidayat et al. 2023). study revealed that technology-assisted sports learning environment in Indonesian schools significantly increased intrinsic motivation ($\eta 2 = 0.31$) and intrinsic motivation was positively correlated with post-test performance ($r = 0.54$, $p < 0.001$). learning environment in Indonesian schools significantly increased intrinsic motivation ($\eta 2 = 0.31$) and was positively correlated with post-test performance ($r = 0.54$, $p < 0.001$). The novelty effects of the ball launcher and the self-pacing abilities of the ML cycle in which students who achieve mastery earlier engage in enrichment activities rather than waiting for slower peers are both theoretically related to increased self-determination and intrinsic motivation (Song 2024). demonstrated that achieving mastery criteria in the ML setting encourages a growth mindset orientation, with students attributing outcomes to effort and strategy rather than innate ability (Linder, Jörg, and Ziemainz 2022). Transparency in the ML setting encourages a growth mindset orientation, with students attributing outcomes to effort and strategy rather than innate ability (Warburton and Spray 2017).Attributional patterns have been associated with persistence and lower levels of performance anxiety in sport contexts (Trotter et al. 2022).

▪ CONCLUSION

This study gives clear empirical evidence that the Mastery Learning model assisted by a table tennis ball launcher is very effective in improving table tennis basic skills of Grade VIII students at SMP Negeri 3 Cimahi, West Java, Indonesia. In answer to the research questions posed: (1) a statistically significant and practically large improvement was observed from pre-test to post-test (mean improvement = 19.62 points; $t(49) = 13.84$, $p < 0.001$; $d = 1.96$); and (2) the 80% mastery criterion was successfully met with 43 of 50 students (86%) achieving the minimum competency standard on the post-test.

The results of this study show that the systematic cyclic nature of mastery learning (diagnostic pretest, prescriptive teaching, formative evaluation, remediative teaching, and enrichment instruction) when combined with the high volume and consistency of practice delivery of an automated ball launcher can significantly improve student achievement in a complex sport skill domain. The intervention is feasible to be implemented in Indonesian public secondary schools with one ball launcher for 50 students per class using rotating sub-group scheduling.

Based on these findings, the following recommendations are offered: (1) Physical

education teachers in Cimahi and comparable Indonesian secondary school contexts are encouraged to adopt the ML model with ball launcher assistance for table tennis instruction, particularly for classes with diverse skill entry levels; (2) School administrators and regional education offices should consider investing in table tennis ball launcher equipment as a cost-effective tool for improving PE outcomes; (3) Future research should employ randomized controlled trial designs to strengthen causal inference, include delayed post tests to assess skill retention, incorporate motivational and psychological outcome measures, and replicate findings across multiple schools and geographic contexts; (4) Pre-service and in-service PE teacher education programs should include mastery learning model training as a core pedagogical competency, supported by evidence based guidelines for technology assisted implementation.

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