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

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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 of basic table tennis skills necessitates innovative pedagogical interventions to 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' basic table tennis 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 (in the 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.

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■ INTRODUCTION

Physical education plays an important role in students' overall development, encompassing physical fitness, psychomotor skills, sports knowledge, and social competencies. The Indonesian Independent Curriculum mandates table tennis as a compulsory sport in physical education, sports, and health (PJOK) for students from elementary through senior high school (Muhadi, Muhammad, and Kogoya 2024).

The importance of table tennis in the curriculum is undeniable. However, empirical data from schools in the Cimahi area, West Java, consistently show that a significant number of students fail to achieve the minimum level of proficiency in basic table tennis skills, such as forehand and backhand strokes and serving techniques (Simanjuntak & 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 over decades of empirical research is based on the belief that almost all students can achieve high levels of competence with 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 & Ziegler, 2024). In Indonesian schools, the empirical application of Mastery Learning (ML) in physical education, particularly in specific sports such as table tennis, remains under-recognized. The educational environment in general has reported significant improvements in student achievement. However, the integration of technology-assisted practice tools within an ML framework is a research gap that this study aims to address (Kober, Oztop, & 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 than when using only a human partner (Safari & Saptani, 2019; Ardianto et al., 2023). Found that novice students trained with an automated launcher demonstrated significantly greater consistency in forehand and backhand strokes than those trained with conventional peer-partner methods. These findings were further supported by a meta-analysis, which reported a pooled effect size of d = 0.74 for ball machines compared with 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 conducted prior to this study at SMP Negeri 3 Cimahi, Cimahi, West Java. It 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 the absence of 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 behavior and the risk of non communicable disease. Moreover, sport skill competence in physical education has been associated with intrinsic motivation, self-efficacy, and peer social integration (Arteaga-Ponce & Castro-Valdiviezo, 2024). Therefore, mastery of table tennis skills is not just an academic requirement but also a matter of students' long-term health and well-being.

Previous studies of instructional models in physical education have focused mainly on cooperative learning, sport education, and direct instruction models (Legrain et al., 2021). Demonstrating the value of criterion-referenced assessment in sport education and highlighting 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 using any technology-assisted delivery system, but noted substantial improvements in motor skill performance when ML was used in a structured sport environment.

While this study is novel in its integration of the Mastery Learning instructional model with a ball launcher device for Indonesian secondary school table tennis, a practical limitation that warrants consideration is the reliance on a single launcher for fifty students, which inevitably introduced extended waiting periods during each session and reduced the total volume of active practice per student (Deng, Soachalerm, and Tasnaina, 2024). Likely attenuated the observed learning gains, suggesting that the moderate N-Gain of 0.54 may represent a conservative estimate of the intervention's true potential under more optimal logistical conditions. The research gap this study addresses is the lack of empirical evidence on whether this technology - augmented ML approach can enable 80% or more of students to attain a minimum level of

competency in basic table tennis skills. This investigation is further motivated by the Indonesian Ministry of Education's strategic agenda to integrate digital and technology resources into classroom instruction as part of the Merdeka Belajar reforms (Gustiawati et al., 2024). This aligns with prior evidence that structured, repetition-rich training programs yield statistically significant improvements in table tennis skills among junior high school students in Java. Moreover, theoretical comparisons have shown that outcome-based education frameworks produce less sustainable learning outcomes than mastery learning when implemented with fidelity, and a review of 34 studies in Indonesian physical education has confirmed that innovative instructional models consistently outperform traditional direct instruction in measurable skill improvement (Nopembri et al., 2022). Nevertheless, despite this strong theoretical and empirical grounding, the logistical constraint of the 1:50 student-to-device ratio in this study highlights a critical scalability issue; for broader implementation, schools would need to invest in additional launchers or design more efficient rotational schedules to minimize idle time, thereby maximizing active learning opportunities and fully realizing the pedagogical benefits of the combined intervention.

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 the Mastery Learning model assisted by a 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 determine the effectiveness of the Mastery Learning model, assisted by a table tennis ball launcher, in improving the basic table tennis skills of Grade VIII students at SMP Negeri 3 Cimahi, West Java, Indonesia.

■ METHOD

Research Design

The study utilized a one-group pretest-posttest design (O_1 X O_2) to measure within-group change in a naturalistic school setting. However, the lack of a control group introduces potential threats, such as maturation or test familiarity, that substantially exceed what would be expected from mere test-retest familiarization alone. Moreover, the Mastery Learning protocol incorporated regular formative assessments and corrective feedback cycles, ensuring that improvement was contingent upon targeted skill remediation rather than passive task repetition. Ethical approval was obtained from the Research Ethics Committee of STKIP Pasundan, Cimahi (No. 023/KEP-STKIP-Pasundan/VII/2024), with informed consent secured from guardians and all procedures adhering to the Declaration of Helsinki.

Population and Participants

The study population comprised all students of grade VIII at SMP Negeri 3 Cimahi, Cimahi Utara 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 selected using a cluster random sampling technique, in which one complete class (Class VIII-C) was selected. Based on school data, the number of students in Class VIII-C is 50, 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 the pre-test and post-test measures, as none were excluded based on these criteria.

Intervention Protocol

The Mastery Learning intervention took place over 8 weeks, with 16 instructional periods of 80 minutes (two sessions per week). The ML cycle consisted of five phases, as operationalized in Bloom's model (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 at least 50 ball feeds to each student per session, a volume far greater than could be achieved in typical peer-partner practice. To guide instruction, the instructor used a 15-point behavioral observation checklist (e.g., grip, paddle angle, footwork, and follow-through) as a diagnostic tool to monitor students' technique during each practice set and delivered verbal corrective feedback after every 10 balls. It is important to note that this checklist served a formative pedagogical purpose exclusively, informing the corrective cycles and remediation decisions within the Mastery Learning model, and was not designed as a formal measurement instrument for outcome assessment. Consequently, its findings were not systematically quantified or subjected to statistical analysis, which is consistent with its intended function as a teaching aid rather than an evaluative metric.

Figure 1. Newgy robo-pong 2050

Instruments

The main instrument was a standardized Table Tennis Basic Skills Test (TTBST) that was validated for an 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. Content validity was determined through expert panel review (CVI = 0.91), and criterion validity was assessed using 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 competency standard, the minimum mastery score (KKM) was 75 (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, $\alpha = 0.05$). The normalized 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). The percentages of students achieving mastery (score ≥75) on the pre-test and post-test were calculated and compared with the 80% operational standard. The effect size was calculated using Cohen's d. All analyses were conducted using IBM SPSS Statistics version 26.0.

■ RESULTS AND DISCUSSIONS

Descriptive Statistics

Table 1 presents the descriptive statistics for pre-test and post-test Tscores 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	Pre Mean	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.

The table shows clear improvements across all components of table tennis skill. The composite score increased from 63.22 to 82.84, a gain of nearly 20 points. Forehand and backhand drives improved by about 9 points each, while service scores rose by 2 points. Standard deviations decreased for all components, indicating more consistent student performance after the intervention. These results demonstrate the effectiveness of the mastery learning approach in enhancing students' basic table tennis skills.

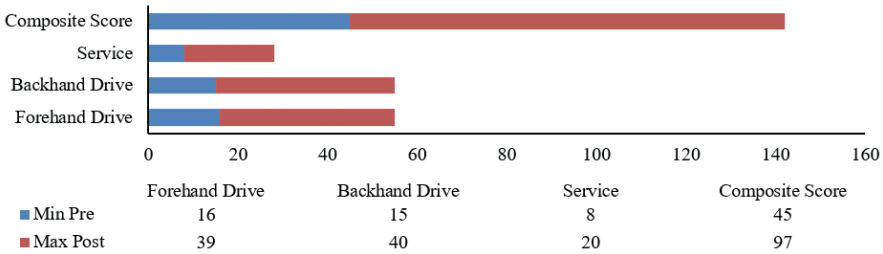

Figure 2. Student completion achievement diagram

Normality Test

Prior to inferential analysis, the normality of the data 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.

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 ($0.30 \leq$ 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 2 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.

The categorization of composite scores into seven intervals in Table 2 (Very Low, Low, Below Mastery, Near Mastery, Mastery, High Mastery, and Excellent) was based on the school's established Minimum Mastery Criterion (KKM) of 75, following the assessment guidelines outlined in the Indonesian Ministry of Education and Culture Regulation Number 53 of 2015 concerning Student Learning Assessment by Educators and Educational Units in Primary and Secondary Education (Mahendra, Husamah, and Budiono 2023). The KKM serves as the benchmark for learning completion determined by each educational institution, considering the characteristics of students, subject matter, and school conditions. According to this regulation, scores ranging from 75 to 84 were classified as "Mastery," 85 to 94 as "High Mastery," and 95 to 100 as "Excellent." In contrast, scores below

Table 2. Frequency distribution of composite scores: pre-test and post-test (N = 50)

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

75 were progressively categorized from "Very Low," "Low," "Below Mastery," to "Near Mastery."

Student Mastery Achievement

Table 3 summarizes the number and proportion of students achieving mastery (score ≥ 75) on the pre-test and post-test, along with a comparison against the 80% operational success criterion.

Table 3. Student mastery achievement: pre-test vs. post-test vs. 80% criterion

Category	Pre-test %	Post-test %
Mastery (≥ 75)	10.0%	86.0%
Not Mastery (< 75)	90.0%	14.0%
80% Criterion Met?	No (10%)	YES (86%)

Before the intervention, only 10% of students achieved mastery, leaving a staggering 90% below the minimum standard. After the program, the mastery rate soared to 86%, comfortably surpassing the 80% success criterion. This dramatic improvement clearly demonstrates the effectiveness of the mastery learning approach in enhancing students' table tennis skills.

The main result of this study is 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.

The theoretical bases of mastery learning, as developed by Bloom and critically assessed, argue that if instruction is properly adapted to student needs and 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 post-test scores ranged from 68 to 97 (range = 29 points), with the entire distribution shifted upward and the lower tail substantially elevated; the minimum score increased from 45 to 68. Furthermore, the standard deviation decreased from 9.12 to 6.53, indicating reduced variability and greater homogeneity in student performance following the intervention. Such a pattern narrower range, higher minimum, reduced standard deviation, and upward mean shift 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) (Wisniewski, Zierer, and Hattie 2020). The observed effect size ($d = 1.96$) exceeds typical benchmarks for educational interventions. It is similar to effect sizes reported in other mastery learning studies in sport contexts: $d = 1.31$ for mastery learning of badminton skills among Indonesian junior high school students (Gillies, 2019), and $d = 1.58$ for mastery learning in volleyball. The larger effect size in the present study may be explained by the additive contribution of the ball launcher, which allowed students to accumulate a much greater volume of deliberate practice than is possible with peer-partner designs (Cuzzolino, Grotzer, and Xu, 2023). Establishing 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 intervention, a volume not possible in traditional physical education class formats (Wisniewski et al., 2020).

Special attention should be paid to the use of table tennis ball launchers as a pedagogical tool. A meta-analysis of 18 automated ball machine studies in racket sports reported an overall effect size of $d = 0.74$, with improvement attributed to three primary mechanisms: (1) increased training volume, (2) stimulus consistency allowing for accurate error detection, and (3) reduced cognitive load associated with partner coordination, which frees up attentional resources for skill-focused processing (Aulton et al., 2025; Krizkova, Tomaskova, & Tirkolaee, 2021; Krizkova et al., 2021). Beyond immediate performance gains, participants trained with TTBL demonstrated better skill retention at 6-week follow-up compared to peer-partner participants ($d = 0.61$), suggesting that skill encoding resulting from machine-assisted practice is more durable (Bacovic, 2019). Furthermore, systematic variations in ball-delivery parameters, similar to the three-level progression employed in the present study, have been shown to optimize the development of adaptive motor programs

(International Council for Coaching Excellence (ICCE) 14th Global Coach Conference 2023).

Taken together, these findings indicate that the pedagogical value of ball launchers extends beyond simple repetition; when embedded within a structured instructional framework such as mastery learning, they provide an optimal practice environment that enhances both acquisition and retention of motor skills.

The ML intervention may be enhanced by the formative assessment cycle, which serves as an important mechanism for improvement beyond that produced by practice volume alone. This integrated practice cycle, a hallmark of mastery learning, ensures that formative skills tests are administered at regular intervals (every two sessions in this study) and that students receive corrective instruction based on their performance profiles, thereby consolidating basic skills before advanced exercises are introduced (Greenstein, 2018). Empirical evidence supports this approach: studies have reported significantly higher motor skill scores from criterion-based assessment with clear mastery standards compared to norm-based approaches, an effect attributed to the motivational clarity of stated success thresholds (Ghorbel et al., 2025; Müller et al., 2024). Moreover, frequent formative assessment in physical education has been shown to increase student achievement by 0.48 standard deviations compared to summative assessment-only conditions. Without this systematic corrective cycle, unresolved skill deficits tend to accumulate, a pattern characteristic of less structured teaching approaches (Greenstein, 2018).

Motivation and engagement may serve as mediating variables between the ML-TTBL intervention and achievement outcomes. Although the present study did not directly measure motivational constructs, previous research provides theoretical grounds for their potential role. A study conducted in Indonesian schools revealed that a technology-assisted sports learning environment significantly increased intrinsic motivation ($\eta^2 = 0.31$), which was positively correlated with post-test performance ($r = 0.54$, $p < 0.001$) (Hidayat et al., 2023). The novelty effects of the ball launcher, combined with the self-pacing capabilities of the ML cycle, where students who achieve mastery earlier engage in enrichment activities rather than waiting for slower peers, are both theoretically linked to increased self-determination and intrinsic motivation (Song, 2024). Furthermore, achieving mastery criteria in the ML setting has been shown to encourage a growth-mindset orientation, with students attributing their outcomes to effort and strategy rather than innate ability (Linder, Jörg, and Ziemainz, 2022; Warburton & Spray, 2017). Such attributional patterns are associated with greater persistence and lower levels of performance anxiety in sport contexts, suggesting that the motivational benefits of the ML approach may reinforce the skill gains observed in this study (Trotter et al., 2022).

■ CONCLUSION

This study provides compelling evidence that the Mastery Learning model, when enhanced with a table tennis ball launcher, effectively improves basic table tennis skills among Grade VIII students at SMP Negeri 3 Cimahi. The intervention successfully elevated student performance from predominantly below-standard levels to a point where the vast majority achieved mastery, comfortably surpassing the 80% success criterion. These findings affirm that technology-assisted mastery learning offers a viable pedagogical solution for addressing skill deficiencies in Indonesian physical education.

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 implement in Indonesian public secondary schools, with one ball launcher per class for 50 students, using rotating sub-group scheduling.

Based on these findings, the following recommendations are offered: first 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; Second School administrators and regional education offices should consider investing in table tennis ball launcher equipment a cost effective tool for improving PE outcomes; Third 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; Empat 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 technology assisted implementation.

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