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Development and Evaluation of a Portable Visual Stimulus Rebound Board for Table Tennis Training

Alit Rahmat[1*], Reshandi Nugraha[2], Regi Dwi Septian[3], Muhammad Zaky Al Ghifary[4]
[1,2,3]Universitas Pendidikan Indonesia, Bandung, Indonesia
[4]Universitas Pendidikan Indonesia, Tasikmalaya, Indonesia

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ABSTRACT

Purpose: This study aims to design, develop, and evaluate the feasibility of a visual stimulus based portable table tennis rebound board. This instructional media was developed to facilitate students' independent practice and help improve visual focus and stroke accuracy during table tennis lessons in schools. **Methods**: The research method used is Research and Development (R&D), referring to the 10 step Borg and Gall model. This study involved a sample of 76 participants selected through purposive sampling, divided into three progressive testing phases: (1) preliminary field testing on 6 students (n = 6), (2) main field testing on 30 students (n = 30), and (3) final operational field testing on 40 participants (n = 40) consisting of 12th grade students. Prior to the field trials, the media was evaluated by a validator panel comprising 4 experts (n = 4), namely 2 media/technical experts and 2 subject matter/instructional experts. Data were collected using a questionnaire instrument consisting of 20 statements on a 5 point Likert scale, alongside open ended feedback forms. Quantitative data were analyzed using descriptive percentages and standard deviation (SD), while qualitative data were analyzed through response frequency grouping. **Findings**: The application of a coordinated target area consisting of 12 target boxes with a high-contrast zig-zag design consistently improved the media's feasibility score across all stages. Quantitative assessment began with expert validation, yielding an average score of 78.75% (± 3.25%) from media/technical experts ("Feasible" category) and 83.50% (± 2.10%) from subject matter/instructional experts ("Highly Feasible" category). During the field trials, the feasibility percentage increased to 85.80% (± 2.45%) in the preliminary testing, rose to 89.60% (± 2.10%) in the main testing, and reached a peak of 92.40% (± 1.85%) during the final operational testing ("Highly Feasible" category). Overall, the media experienced a substantial total feasibility increase of Δ = +13.65% from the initial prototype to the final product, accompanied by an increasingly uniform distribution of responses. Furthermore, the analysis of open-ended feedback revealed that 87% of students in the main field testing (n = 30) confirmed that the color cues and alphanumeric coordinate codes significantly helped accelerate their visual focus and improve their stroke direction accuracy. **Research Implications**: This study provides an empirically validated instructional media reference for Physical Education teachers and sports practitioners, proving that the integration of structured visual cues into independent practice equipment effectively assists students in target aiming and enhances the overall effectiveness of table tennis learning in schools. **Originality**: The novelty of this research lies in the transformation of a conventional rebound board into an interactive training medium that combines dual-sided ball rebound with a high contrast alphanumeric target matrix, thereby integrating students' physical agility and cognitive focus engagement within a single independent practice tool.

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INTRODUCTION

Table tennis is a popular small ball sport as it combines recreational elements with the physical activity highly needed to maintain students' physical and mental health (Ishak et al., 2025; Kurniawan et al., 2025). This sport offers the advantage of not requiring a large space; it simply utilizes a table, a net, and a paddle as a striking implement (Herliana, 2019; Ishak et al., 2025). Amidst students' high levels of sedentary behavior caused by computer and gadget usage, table tennis serves as an effective learning medium to improve students' movement quality within school Physical Education programs (Sari & Antoni, 2020). This approach becomes highly significant considering that current student fitness levels are declining and conventional teaching methods are proving to be less effective (Xie et al., 2025). To play well, students are not only required to be physically fit but must also master fundamental techniques such as grip, body positioning, footwork, and stroke techniques (Herliana, 2019; Kurniawan et al., 2025). Specifically for the drive stroke, students require a stable paddle position, precise execution, and consistent target accuracy to ensure optimal gameplay (Haryanto et al., 2025).

Among the various basic technical components, mastery of stroke techniques, particularly the forehand drive, is a primary factor determining a player's performance in active gameplay (Asri et al., 2017; Herliana, 2019). The drive stroke is defined as a striking technique utilizing a long swing and a closed paddle face, which produces a flat, fast, and low-spin ball trajectory (Suwanto, 2024). Mastery of this technique is crucial as it serves as the primary foundation for students to control rallies while scoring points (Gusman et al., 2025). Nevertheless, from a sports science perspective, stroke effectiveness is not solely determined by the mechanical power of the ball's pace, it also relies heavily on cognitive aspects, such as accuracy and consistency in placing the ball into hard to reach areas of the opponent's table(Gusman et al., 2025; Herliana, 2019). Furthermore, for students beginning to learn offensive patterns, the ability to execute powerful strokes must be balanced with sensorimotor sensitivity to differentiate between a flat, powerful stroke (drive) and a soft, rotating stroke (spin), thereby making it difficult for the opponent to predict the ball's trajectory (Anggara, 2021). The ability to accurately place the ball requires excellent hand-eye coordination, postural stability, concentration, and profound adaptation to the dynamic learning situations on the court (Asri et al., 2017; Sariul et al., 2022; Syafputra et al., 2026).

A common issue frequently encountered in table tennis learning at schools is the students' low stroke accuracy, where the ball often hits the net or goes out of bounds due to a lack of spatial awareness and delayed visual processing (Gusman et al., 2025). This constraint stems from conventional learning processes that tend to be monotonous, coupled with the lack of independent learning media capable of simulating real game situations that require rapid visual decision-making (Faisal et al., 2025; Ilham et al., 2025). To maintain learning motivation and prevent boredom, structured and varied instructional modifications are highly necessary to optimize movement automation and students' visual attention focus (Antoro et al., 2025; Asri et al., 2017). Several instructional media innovations have indeed been developed to address these issues, such as the Rocket Spin device, which focuses on ball spin manipulation (Faisal et al., 2025), paddle modifications for directional control (Ilham et al., 2025), and the use of the multiball method to increase stroke repetitions (Antoro et al., 2025). However, currently available independent learning media generally lack an integrated visual feedback system. Consequently, students find it difficult to synchronize their physical movements with dynamic visual cues, thereby creating a gap in a learning process that requires the integration of technical motor skills and cognitive visual training. Recent evidence in digital sports education addresses this gap by demonstrating that the application of a Technological Pedagogical Content Knowledge (TPACK) based framework such as AI based intelligent analysis, automatic ball-launching robots, and immersive simulations can significantly accelerate skill mastery and enhance students' physical fitness compared to traditional teaching methods (Xie et al., 2025).

Although various independent learning media are currently widely available, these tools generally lack an integrated visual feedback system. This restricts their effectiveness in training students' spatial adjustments directly on the court. Preliminary observations and interviews conducted during the pre-development phase at several schools confirmed this issue: as many as 85% of Physical Education teachers stated that students' visual focus and attentiveness remain exceptionally low when practicing with conventional static rebound boards. To overcome these limitations, this study introduces a visual stimulus-based rebound board designed to actively bridge the execution of technical strokes with visual focus. Specifically, this study formulates the following three research questions:

1. How is the visual stimulus based portable rebound board systematically designed and validated by experts?
2. What is the empirical feasibility level of the developed instructional media across progressive small and large scale field trials?
3. What are the perceptions of students and Physical Education teachers regarding the tactical utility and operational constraints of this tool during independent practice?

Developing effective instructional media in Physical Education requires a profound understanding of students' movement needs and learning psychology. In table tennis, students are required to respond to fast paced ball trajectories within a limited time frame (Safari & Saptani, 2019). This condition demands excellent hand-eye coordination so that students can precisely synchronize their visual focus with their hand movements (Safari & Saptani, 2019). However, conventional teaching methods in schools often fail to attract students' learning interest. Field evidence indicates that low learning motivation in Physical Education directly results in passive student attitudes, high distractibility, and a reluctance to participate in practical exercises, thereby reducing overall learning effectiveness (Irawan et al., 2024). Furthermore, traditional sports education in schools has been heavily dominated by low level physical movement repetitions, without cultivating students' Higher Order Thinking Skills (HOTS) (Jumarin et al., 2026). To overcome these limitations, this study introduces an innovative table tennis rebound board redesigned with a 12 box alphanumeric target matrix, aligning with the current development trends of interactive sports training aids (Nurhidayat et al., 2026).

METHOD

This study employs a Research and Development (R&D) approach referring to the Borg and Gall development model through 10 comprehensive development steps. This approach was chosen to design, develop, and simultaneously test the feasibility of an interactive table tennis rebound board equipped with a target board consisting of a 12 box alphanumeric matrix. In the context of physical education, the primary objective of the R&D method is to develop innovative products that can serve as practical solutions for overcoming boredom and improving the quality of student learning in schools. To ensure the resulting product is thoroughly valid and effective, the implementation of this research followed the 10 standard steps of the Borg and Gall model as follows: (1) research and information collecting, (2) planning, (3) preliminary product development, (4) preliminary field testing, (5) main product revision, (6) main field testing, (7) operational product revision, (8) operational field testing, (9) final product revision, and (10) dissemination and implementation. This structured development process ensures that the initial media draft can be progressively refined into instructional media ready for use in schools, aligning with the principles of modern sports equipment engineering and Physical Education curriculum validation standards (Jumarin et al., 2026; Rahayu, 2025).

Following the initial design phase, the research proceeded to field trials involving 12th grade students who engaged in independent table tennis practice using the developed rebound board. To quantitatively evaluate the feasibility of the media, the overall implementation of these trials involved a cumulative sample of 76 participants, consisting of students and Physical Education teachers. This total of 76 participants was derived from the accumulation of three progressive testing waves, namely: (1) a preliminary field testing group involving 6 students (n = 6), (2) a main field testing group of 30 students (n = 30), and (3) a final operational field testing group comprising 40 students (n = 40). To measure the students' stroke accuracy on the alphanumeric target matrix, the training process utilized a structured distributed practice pattern. This progressive training scheme aligns with racket sports training methods that have proven effective in optimizing motor skill mastery, enhancing hand-eye coordination, and maintaining movement consistency within authentic school learning environments. Prior to conducting the trials, research ethics were strictly implemented through written and verbal informed consent from all participating students and Physical Education teachers, ensuring that participation was completely voluntary and student data confidentiality was firmly maintained.

The data collection instruments used in this study included expert assessment rubrics (encompassing language, subject matter, and media design aspects), practicality questionnaires for Physical Education teachers, and student response questionnaires. All of these instruments were measured using a 5 point Likert scale (ranging from a score of 1 for 'very poor' to 5 for 'excellent') to quantify feedback from experts and users. Before the field trials were conducted, the initial draft of the media was first evaluated through a structured discussion forum with experts and peers to assess the suitability of the media design. The numerical data obtained from the expert assessment sheets and student questionnaires were subsequently calculated and analyzed using a descriptive percentage technique. To interpret the obtained feasibility percentages, the final scores were converted into qualitative categories based on the following five standard feasibility criteria intervals: 81% – 100%: "Highly Feasible" category; 61% – 80%: "Feasible" category; 41% – 60%: "Moderately Feasible" category; 21% – 40%: "Less Feasible" category; and 0% – 20%: "Highly Unfeasible" category. The grouping of these percentage interval ranges refers to the standard product evaluation criteria in physical education R&D, where the feasibility of the developed tool is determined based on the consensus of validity scores from experts and user feedback in schools (Jumarin et al., 2026; Rahayu, 2025).

RESULTS

In the initial stages of the development cycle, which included information collecting and planning, baseline data regarding spatial constraints and students' movement coordination needs in school table tennis learning were carefully collected. These baseline data served as the primary reference in the preliminary product development stage. At this stage, the initial prototype of the table tennis rebound board was created with a dual-sided rebound configuration, specifically designed to facilitate students' independent practice in schools. Before being tested directly on students, the prototype was first evaluated by experts to assess the feasibility of its physical structure and instructional aspects. The first assessment was conducted by 2 technical and media experts (n = 2) who evaluated the physical durability, construction, and safety of the equipment. From the recapitulation of the questionnaire results from both media experts, an average feasibility percentage score of 78.75% was obtained, with a standard deviation (range of response variation) of ± 3.25%. Based on the feasibility interval criteria, this 78.75% figure falls within the 61%–80% range, thus categorizing the physical framework of the product as Feasible.

Simultaneously, the second assessment was conducted by 2 subject matter and instructional experts (n = 2) to evaluate the media's alignment with the Physical Education curriculum and learning objectives. The calculation of the questionnaire scores from these two instructional experts yielded an average feasibility percentage score of 83.50% with a standard deviation of ± 2.10%. This score of 83.50% falls within the 81%–100% range, classifying the media into the "Highly Feasible" category from a pedagogical perspective. In addition to the numerical assessment, the experts also provided qualitative feedback emphasizing the importance of increasing the color contrast on the alphanumeric target area to make it easier for students to focus their visual attention during visual tracking exercises.

This refined prototype was subsequently tested in the Main Field Testing stage, involving 30 students (n = 30) at the school. The recapitulation of the questionnaire results from these 30 students demonstrated an increase in the average feasibility score to 89.60% with a standard deviation of ± 2.10%, confirming that the media falls into the "Highly Feasible" category. At the final stage, the rebound board underwent Operational Field Testing involving a total of 40 twelfth grade students (n = 40). The quantitative evaluation during this operational testing stage, calculated from student questionnaires, yielded a peak feasibility score of 92.40% with a standard deviation of ± 1.85%. This figure indicates that the alphanumeric target board media falls into the "Highly Feasible" category for widespread implementation in school Physical Education learning.

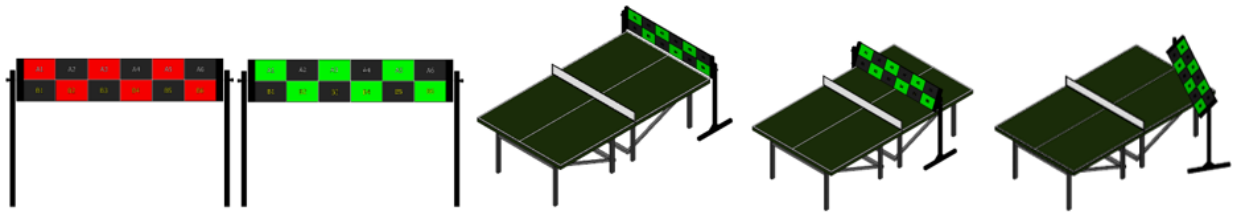

Figure 1. 3D visual design of the portable dual surface rebound board featuring target matrices and multi position configurations on a table tennis table.

In addition to quantitative scoring assessments, the frequency trends of open-ended student responses during the Main Field Testing (n = 30) were also analyzed. From the categorization of the written responses of these 30 students, 26 students (87%) explicitly stated that the contrasting zig-zag color pattern alongside the alphanumeric coordinate codes significantly helped accelerate their visual focus in selecting targets instantly during practice sessions. On the other hand, the use of a matte black frame proved effective in isolating students' visual focus onto the target area without distraction from light reflections within the sports hall. This level of assessment consistency is further reinforced by a very low standard deviation of 1.85% during the Final Operational Field Testing stage. This small standard deviation statistically demonstrates a very strong consensus between students and Physical Education teachers, indicating that the progressive design refinements successfully addressed various operational constraints encountered during the early development stages. To provide a comprehensive overview of the product's feasibility improvement across stages, the quantitative data recapitulation and the distribution of media feasibility scores throughout all R&D validation and testing phases are systematically presented in Table 1.

Table 1. Feasibility Percentage and Score Distribution Optimization Across R&D Phases

R&D Evaluation Phase	Evaluator Subject Group	Sample Size (n)	Percentage Mean (*M*)	Standard Deviation (SD)	Empirical Classification
Pre-Testing Baseline	Engineering Experts	2	78.75%	3.25%	Feasible
	Instructional Coaching Experts	2	83.50%	2.10%	Highly Feasible
Preliminary Field Testing	Small Scale Users	6	85.80%	2.45%	Highly Feasible
Main Field Testing	Intermediate Users	30	89.60%	2.10%	Highly Feasible
Operational Field Testing	Large Scale Users	40	92.40%	1.85%	Highly Feasible

Note: The score progression in Table 1 shows a continuous increase in the media's feasibility percentage from the initial prototype to the final product, with a total increase Δ of +13.65%. This increase is derived from the difference between the initial prototype evaluation score by media experts (78.75%) and the final operational field testing score in schools (92.40%). Along with this increasing feasibility score, the decreasing standard deviation (reducing from ± 3.25% in the initial stage to ± 1.85% in the final stage) demonstrates that the level of agreement and satisfaction among students became increasingly uniform and consistent regarding the quality of the developed media.

During the Final Product Revision phase, all major structural modifications to the rebound board were completed, shifting the focus entirely to refining ergonomic comfort and safety quality control for students. Several minor fabrication flaws, such as uneven welding points and sharp edges on the lower mounting plate, were successfully smoothed out through meticulous sanding. Subsequently, repainting using anti rust coating was performed to guarantee the safety and durability of the media during student use in Physical Education learning.

This entire series of R&D activities culminated in the Dissemination and Implementation phase. In line with the academic scope of this study, dissemination efforts did not focus on industrial scale commercialization, rather, they were intended to share the equipment design, empirical data, and media development methodology through open access scientific publications in reputable journals. This step is expected to serve as a valid scientific reference regarding table tennis instructional media for Physical Education teachers, researchers, and the broader educational community.

DISCUSSION

The application of the target area in the form of a 12 box alphanumeric matrix (divided into A1–A6 and B1–B6 areas) on the developed rebound board serves two main functions: improving students' technical stroke accuracy while simultaneously stimulating cognitive focus (cognitive engagement) during independent practice at school. In racket sports such as table tennis, the ability to accurately direct the ball to a designated target area is a primary indicator determining the quality of student skills (Safari & Saptani, 2019). This stroke accuracy heavily relies on the visual system, where precision in movement is characterized by rapid eye movements (saccadic eye movements) in tracking the ball's trajectory (Nakazato et al., 2024) as well as efficient gaze anchoring to process information rapidly (Shinkai et al., 2025). By accustoming students to alternating their gaze between the ball rebound and the contrasting alphanumeric target area, this rebound board naturally trains students' visual responses and gaze focus similarly to real match situations.

Through the flexibility of the target arrangement on this rebound board, Physical Education teachers can schedule structured repetitive training (distributed practice) to optimize physical movement mastery and maintain student stroke consistency during independent learning (Safari & Saptani, 2019). This aligns with the concept of motor adaptation, which indicates that clear, goal oriented visual cues are crucial for sharpening coordination between visual perception and students' movement actions (Xiang et al., 2026). In addition to providing benefits for physical movement accuracy, the availability of this target area also positively impacts students' learning psychology. The importance of maintaining learning motivation is empirically proven by research in physical education, which found a correlation coefficient value of r = 0.604, indicating a strong positive relationship between students' motivation levels and learning outcome effectiveness in Physical Education subjects (Irawan et al., 2024).

The interactive approach of this media directly supports the paradigm shift in Physical Education learning, which now emphasizes the integration of Higher Order Thinking Skills (HOTS), such as the ability to analyze and evaluate movements during independent practice (Jumarin et al., 2026). Findings in sports pedagogy reinforce this direction, where the use of interactive devices has proven capable of enhancing students' motor learning outcomes while creating a more student centered learning environment (Müller & Wagner, 2026). The importance of applying higher-order thinking skills in Physical Education subjects aligns with current trends in instructional instrument development. This is evidenced by reference research that recorded a material feasibility score of 93.33% and an evaluation expert score of 91.66% for HOTS based Physical Education learning instruments (Jumarin et al., 2026).

The high achievement of these previous studies is highly relevant to the empirical upward trend in this research. Through the implementation of the 10 stage Borg and Gall development model, the developed rebound board successfully achieved a peak feasibility score of 92.40% with a standard deviation of ± 1.85% (the "Highly Feasible" category) during the Final Operational Field Testing stage in schools. The increase in the feasibility percentage with a difference value Δ of +13.65% representing a rise from the initial media expert prototype evaluation score (78.75%) to the final school score (92.40%) reinforces a core principle in educational research and development: that product modifications based on real world field feedback are effective in eliminating technical constraints and maximizing the practicality of the tool for teachers and students (Rahayu, 2025). Thus, this rebound board media can serve as a new reference for independent sports instructional tools that meet the standards of physical structure and pedagogy in modern sports equipment engineering (Nurhidayat et al., 2026).

Although this table tennis rebound board media received a highly feasible rating, this study still has two main methodological limitations. The first limitation lies in the scope of the research subjects, which remains limited to a sample group in a specific school (purposive sampling), thus, the results of this study cannot be fully generalized to all school characteristics and educational levels. The second limitation lies in the evaluation instruments, which still focus on practicality assessments and qualitative perceptions through descriptive questionnaires (a non-experimental design), without directly measuring changes in students' cognitive responses and movement accuracy in the field in real time.

Therefore, future research is highly recommended to experimentally test the effectiveness of this media through a more measurable approach. Subsequent researchers can integrate advanced technology based instruments, such as an eye tracking system and biomechanical motion analysis, to precisely prove the impact of using this alphanumeric target board on students' visual focus levels and motor coordination enhancement while practicing at school.

CONCLUSION

This study has successfully developed and validated a portable dual-sided table tennis rebound board equipped with a 12-box target matrix (A1–B6 coordinates) through the comprehensive 10 procedural development stages of the Borg and Gall model. This research and development process demonstrated a consistent upward trend in feasibility scores across every stage. This is evidenced by the increase from the initial media expert evaluation score of 78.75% (the "Feasible" category) to a peak feasibility score of 92.40% with a standard deviation of ± 1.85% (the "Highly Feasible" category) during the Final Operational Field Testing stage with students in Physical Education learning. The total feasibility increase with a difference value Δ of +13.65% proves that tool refinements based on direct user feedback particularly through the use of high contrast zig-zag color patterns, spatial coordinate codes (A1–B6), and anti-reflective matte coatings are effective in overcoming practice boredom and the limitations of conventional instructional aids in schools.

From a pedagogical perspective, this developed instructional media introduces a novel innovation for independent training equipment that successfully bridges physical agility with students' cognitive processes. Through the utilization of a goal-oriented target matrix combined with structured practice schedules, this rebound board not only enhances stroke accuracy and hand-eye coordination but also stimulates students' analytical thinking skills (Higher Order Thinking Skills) during independent practice. Ultimately, this portable rebound board meets both modern sports equipment engineering standards and current Physical Education curriculum requirements, making it highly feasible and recommended for widespread implementation in schools to enhance learning motivation and the effectiveness of table tennis instruction.

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AUTHOR CONTRIBUTION STATEMENT

AR was responsible for conceptualization, methodology, field investigation, data curation, and drafting the original manuscript. MZAG contributed to the initial conceptualization, product design, mechanical-visual layout engineering, and visualization. RN and RDS provided technical validation support, formal data analysis, and resource coordination. All authors actively participated in the manuscript writing, review, and editing phases, and have collectively read and agreed to the final published version of the manuscript.

AI DISCLOSURE STATEMENT

The authors utilized Gemini (Google) during the preparation of this work solely to assist in translating the manuscript from Indonesian into English and refining the linguistic structures according to the journal's formatting guidelines. Following the use of this service, the authors thoroughly reviewed, verified, and edited the entire content to guarantee academic accuracy and absolute alignment with the required publication standards.

***Alit Rahmat (Corresponding Author)**
Faculty of Sports and Health Education,
Universitas Pendidikan Indonesia,
Jl. Dr. Setiabudhi 229, Bandung, West Java, 40154, Indonesia
Email: alitrahmat@upi.edu

Reshandi Nugraha
Faculty of Sports and Health Education,
Universitas Pendidikan Indonesia,
Jl. Dr. Setiabudhi 229, Bandung, West Java, 40154, Indonesia
Email: reshandi@upi.edu

Regi Dwi Septian
Faculty of Sports and Health Education,
Universitas Pendidikan Indonesia,
Jl. Dr. Setiabudhi 229, Bandung, West Java, 40154, Indonesia
Email: regidwiseptian@upi.edu

Muhammad Zaky Al Ghifary
UPI Regional Campus Tasikmalaya,
Universitas Pendidikan Indonesia,
Jl. Dadaha No. 18, Tasikmalaya, West Java, 46115, Indonesia
Email: zakyalghifary79315@gmail.com