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Development of a Learning Visual Aid for Parabolic Motion in Terms of its Validity and Effectiveness

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Abstract

This study aims to develop a learning aid for the topic of parabolic motion based on air pressure, using a modified 4D development model reduced to 3D. The parabolic motion teaching aids commonly used in schools generally employ manual spring-based launchers, which make it difficult to control the launch velocity. Therefore, this research developed an air pressure-based teaching aid that allows for the adjustment of variables such as launch angle, initial velocity, pressure, maximum height, maximum range, and flight time. The research was limited to the development stage (limited trials) without proceeding to the dissemination phase. The validity of the device was assessed by five validators, consisting of four lecturers and one teacher. The effectiveness of the device was evaluated using response questionnaires administered to 18 students and one physics teacher from Grade XI at SMA Plus Muhammadiyah Merauke in the 2023/2024 academic year. The validity test results showed an average score of 81.2 (81.2%), categorized as very valid, with a minimum validity threshold of 61%. The validation instrument consisted of 20 items. The effectiveness test based on teacher responses yielded a score of 56.72 (76%), categorized as effective, obtained from 10 questionnaire items. Meanwhile, student responses resulted in a score of 43 (86%), categorized as very effective, obtained from 15 questionnaire items. The learning outcome test, consisting of 15 questions, showed an average score of 83.3, with 94% of students achieving scores above the minimum mastery criterion (MMC = 70). Therefore, the air pressure based parabolic motion teaching aid developed in this study is proven to be highly valid, effective, and feasible for use as a learning medium in teaching parabolic motion.

Keywords: Validity; Effectiveness; Learning Visual Aid; Parabolic Motion

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INTRODUCTION

The development of instructional technology and the demand for more contextualised and engaging science education compel teachers and researchers to design innovative and meaningful learning media. With the advancement of science and technology, the demand for education is increasing (Syaripudin et al., 2023). Several factors influence educational quality. Education plays a pivotal role in shaping human resources capable of responding to the challenges of the 21st century, where knowledge, creativity, and innovation are central to sustainable development (Raisal, 2025). One of these is the learning resources that can foster students' knowledge and understanding (Saraswati, 2020). The pivotal role of education in shaping students' mindsets and skills toward more positive and progressive outcomes is realised through the teaching learning process across diverse disciplines, one of which is physics (Rusdiana & Juanda, 2019).

One physics concept often regarded as abstract and difficult for students to comprehend is projectile motion, especially when it involves analysis of horizontal and vertical components as well as variations in launch angle and velocity. Physics education continues to face challenges, especially in teaching topics with abstract concepts (Cabal & Basagre, 2025). Physics learning must be designed to ensure that students can connect abstract concepts with real world applications while also developing science process skills (Wiyatmo, 2025). To bridge the gap between theoretical concepts and students' real-world experiences, a teaching aid that visualises the principles of projectile or parabolic motion becomes an important necessity. Physics education aims to equip learners with knowledge, understanding, and the ability to develop science and technology (Risamasu & Pieter, 2025). Physics instruction, in essence, is an educational method aimed at creating a situation in which students can understand principles, concepts, and skills, and cultivate a sense of inquiry with the objective of advancing science and technology (Muhammad, 2019). Physics learning activities require the implementation of practicum using teaching aids in order to enhance students learning outcomes and knowledge (Sipahutar, 2022). The success of the learning process is closely associated with supporting variables, among which are teachers, instructional media, and students (Rahayu, 2023a).

A good instructional media does not merely display phenomena, but must also exhibit validity (alignment with the learning objectives and the concepts to be taught), effectiveness (that is, the media ability to improve students learning outcomes) and support the overall success of the learning process (including motivation, engagement, conceptual understanding, and transfer of learning). Although numerous studies have been conducted regarding the use of instructional media in physics education, there remain specific limitations particularly in the development of air pressure based projectile launchers to visualise projectile (parabolic) motion in a tangible, interactive, and school safe manner. One of the topics studied in physics is projectile motion. The subject of projectile motion is closely linked to everyday life yet inherently abstract, thus necessitating a medium that can assist in understanding and explaining its underlying concepts. Physics, as a science that investigates, provides evidence for, examines, and explains the existence of objects and phenomena, requires more than mere lecture delivery if the topic is to be well understood. If the material is only presented via a lecture method, then students will only receive it in the form of formulas or abstract concepts. This causes students to struggle in truly comprehending the actual concept of physics (Rizaldi et al., 2023). Physics is the study of natural phenomena and the environment. Therefore, Physics is called a branch of Natural Science or Science (R A R, 2021).

Physics learning is often perceived as difficult by students because it involves abstract concepts, many formulae, and phenomena that are not always directly observable. Instructional aids act as a bridge between theory and real experience, thereby playing a critical role in learning. Physics learning activities require practical work using instructional aids in order to enhance learning outcomes and students' knowledge (Sipahutar, 2022). The success of practical laboratory activities in the physics teaching-learning process undoubtedly depends on the availability of adequate equipment, including instructional aids (Rahayu, 2023b). Student engagement is an important predictor of learning success, as teaching materials that stimulate interest and are easy to understand tend to foster greater motivation and participation (Usman, 2025). Based on the literature and previous research, the use of physics instructional aids can increase students' interest and understanding. Constructivist theory asserts that learning occurs when individuals actively build their own knowledge through experience and interaction with the environment. Physics is the study of natural phenomena and the environment.

In the topic of projectile motion, students must understand that an object moves simultaneously with horizontal and vertical components, is influenced by a constant vertical acceleration due to gravity, and produces a parabola shaped trajectory. This is a concept that cannot be fully grasped by formulas or two-dimensional diagrams alone. A teaching apparatus also enables students to see how constant vertical acceleration (owing to gravity) and constant horizontal velocity (in the ideal case) combine to yield a parabolic path that is, the combination of two motions occurring concurrently. The air pressure based projectile motion demonstrator, in which a projectile is launched by compressed air and then released to follow a parabolic trajectory, allows the initial speed (v_0) of the projectile to be varied (for example by controlling the pressure, the launch angle, or the air release valve). With adjustable launch angle and initial speed, experiments can directly explore key parameters of projectile motion: range, maximum height, and flight time. The advantage of the air pressure version over simpler versions (manual launch, spring based, or merely hand thrown) lies in better control of the initial variables, more consistent repetition, and a stronger visual experience for learners.

The effective control of an air pressure based parabolic motion apparatus involves several interrelated aspects, namely the initial air pressure, which can be adjusted using a pressure regulator gauge (figure 3, no. 6) with a maximum measurement capacity of 4 kPa, the launch elevation angle, which is measured accurately using a mini digital protractor with a precision of ±0.1° (figure 3, no. 8), and the mechanical stability of the launcher (figure 3, no. 11). Stable air pressure ensures that the initial velocity of the launched object remains relatively constant from one trial to another, allowing the results to be compared and analyzed with the ideal parabolic motion model. The elevation angle determines the vertical and horizontal components of the launch velocity; therefore, precise measurement and adjustment of the angle are crucial to ensure that the trajectory aligns with the theoretical equations.

In practice, the control strategy includes: using the regulator to set the air pressure precisely, ensuring there are no air leaks that could alter the initial velocity, maintaining a rigid launch base to prevent displacement during launch, systematically adjusting the angle, and repeating identical conditions to obtain reliable data. This apparatus offers a powerful visual and interactive experience because a pressure launched projectile tends to produce a clear parabola, with easily observed horizontal and vertical parts students can more readily observe the horizontal motion component (constant velocity) and the vertical motion component (uniformly accelerated motion) simultaneously and thus reinforce their conceptual understanding. Physics learning requires students to conduct more research, experimentation, and practical work. Through such experiments and practicum activities, students can explain phenomena that occur in nature (Azmi, 2023).

The air pressure-based teaching aid has greater advantages compared to the spring based or manual projectile launcher, as it allows more flexible adjustment of initial variables such as launch angle and air pressure, enabling better control of initial velocity and trajectory. The development of a simple launcher shows that this teaching aid is suitable for parabolic motion lessons in schools, although spring based launchers often struggle to maintain consistent launch velocity (Salam, 2019). Meanwhile, the PhET simulation has proven effective in enhancing the understanding of parabolic motion concepts and improving learning outcomes(Meka Jane C, 2025). The PhET *Projectile Motion* virtual simulator excels in visualizing trajectories and modifying variables quickly and safely, without physical risk, but it lacks the tangible experience and physical engagement offered by real teaching aids. On the other hand, low-cost PVC launchers provide hands-on experimentation opportunities at minimal expense, but they typically have limitations in accurately measuring variables (such as initial velocity) and in achieving consistent measurement results. One aspect that remains a challenge for the air pressure-based launcher is the technical preparation and calibration process, which requires a relatively long setup time.

Based on the foregoing exposition, it is necessary to develop a teaching aid that can provide a meaningful learning experience for students. The selection of the topic of projectile motion in the development of the teaching aid is justified by the fact that, after conducting a needs analysis survey, 71% of XI grade students at SMA PLUS Muhammadiyah Merauke agreed that a teaching aid is required in the learning process especially for the topic of projectile motion. Projectile motion is a subject that is often considered quite difficult in physics learning, and thus requires visualization via instructional media to facilitate understanding (Rosita et al., 2020). Needs analysis is a process to determine the priority of various data collection tools that can provide an overview of student learning progress and determine the difference between the desired/should or common conditions with the existing conditions in the physics assessment used (Arifin & Sani, 2021). Therefore, a media that can help explain the concept of this topic is required. The suitable media is a teaching aid, which assists the concept comprehension process through concrete objects. The use of a teaching aid can help students directly observe and study a body that is projected and follows a parabolic trajectory, thereby stimulating student interest and motivation in learning physics. One of the solutions to the problem mentioned above is to create learning media that can capture students' attention and serve as a tool to facilitate the learning process (Rahman et al., 2023). Based on the initial research analysis until now, a projectile motion teaching aid has not yet been available in the school. Hence, this study aims to develop an air pressure based projectile motion teaching aid and to test the levels of validity, effectiveness, and learning achievement produced by using the device in the physics class. It is expected that the results of this study will make a valuable contribution both to the development of physics instructional media and to secondary school teaching practice as an alternative to strengthen conceptual understanding of projectile motion in a visual and experiential manner.

METHOD

Research Type and Design

This study employs a Research and Development (R&D) approach and uses the four-D (4D) development model originally introduced by S. Thiagarajan et al., which is structured into four primary phases: Define, Design, Develop, and Disseminate. The development used 4D but steps are limited to 3D step as define, design, develop than validated by experts (Hartono et al., 2025). In the present investigation, the focus is delimited to the Develop (3D) as shown in Figure 1, which the instructional aid is produced and its validity and effectiveness are rigorously assessed. Research and Development also means that in a new product, there is investigation or improvement. Research can be defined as data and information that is systematically collected and advances knowledge in any field in the form of analysis (Kurnia et al., 2024). Specifically, after the preceding phases of need analysis and design specification, the air-pressure-based projectile motion teaching apparatus has been developed (see Figure 2) and subjected to a limited trial to evaluate its construct validity, practical effectiveness, and student learning outcomes.

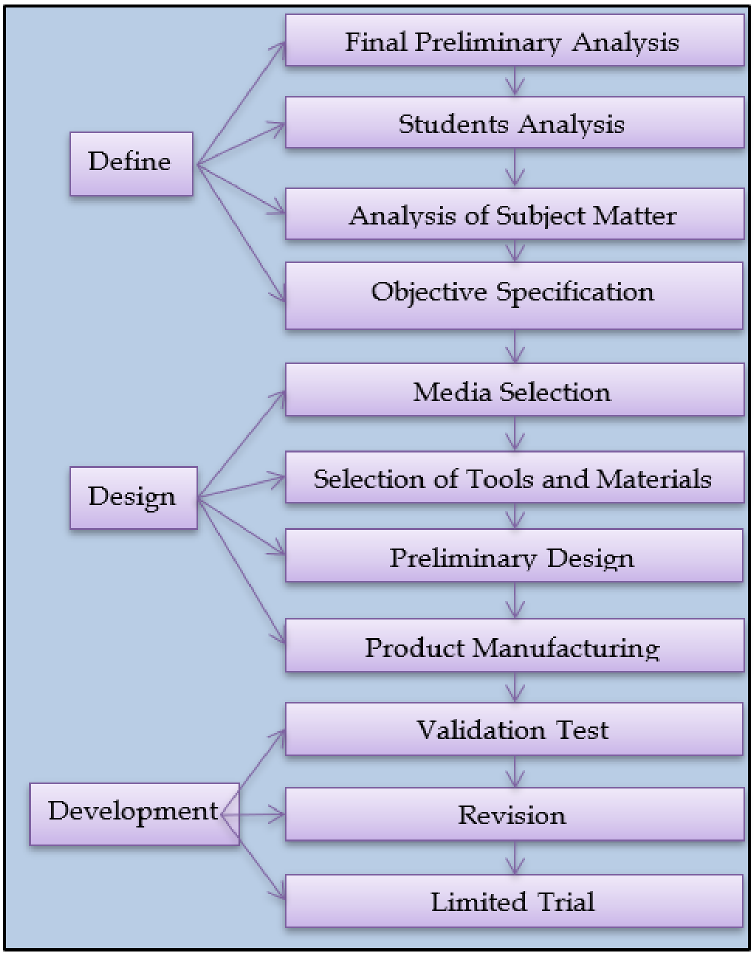
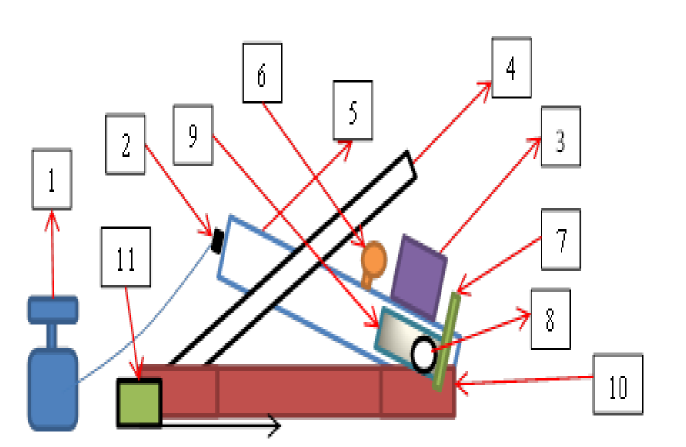


Figure 1. Research Flow

The decision to restrict the scope to the development and testing phases is intentional, given that extended dissemination and wide-scale implementation will follow once foundational validity and efficacy are confirmed. The apparatus under development was evaluated in a controlled environment to ascertain whether the product meets predetermined criteria of validity (by expert review), effectiveness (by pre post student performance measures), and learning achievement (by comparing outcomes with conventional instructional methods). Through this approach, the study aims to provide empirical evidence that the newly developed teaching aid is not only feasible but also beneficial in improving conceptual understanding of projectile motion in secondary school physics classes.



NO.	Explanation
1	Air pump
2	Venthole
3	Angle meter
4	Pole
5	Wind tube
6	Air pressure gauge
7	Trigger
8	Marble bullets
9	Bullet holder
10	Base
11	Length measuring instrument

Figure 2. Design of a parabolic motion teaching aid

Research Subject

A limited field trial was conducted at SMA PLUS Muhammadiyah Merauke. A crucial aspect of this study is the information-gathering process, in which data are collected with the explicit purpose of obtaining evidence that supports the achievement of the research objectives. The instruments used in the data-collection phase included: a validation questionnaire for the teaching aid, a teacher-response questionnaire, a student-response questionnaire, and student learning-outcome data. The validation questionnaire was completed by five validators four lecturers from the Physics Education department at Universitas Musamus and one physics teacher from SMA PLUS Muhammadiyah Merauke. This validation questionnaire was used to determine the validity of the developed teaching aid.

The teacher- and student-response questionnaires were employed as methods to examine the effectiveness of the teaching aid. The student response questionnaire was completed by eighteen students of Grade XI in the academic year 2023/2024 at SMA PLUS Muhammadiyah Merauke. The validity testing of the teaching aid plays a very important role in instructional media development research: validity ensures that the teaching aid truly measures or facilitates the intended concept for example, in the context of projectile motion, that the trajectory, the horizontal/vertical components, and the effect of gravity can be observed and understood by students. Without validity, the claim that the aid enhances understanding becomes weak because there is no evidence that the device aligns with the conceptual objective. The success criteria for this study are as follows: a validity test result of ≥ 61%, an effectiveness test result of ≥ 61%, and a learning mastery level of ≥ 70%. The study involves a limited trial in Physics instruction in grade XI at SMA PLUS Muhammadiyah Merauke without a control class. The teaching aid provides a more interactive and concrete experience for students. This increases student interest, active engagement, and enables a more exploratory learning process.

Instrument and Procedure

In the context of developing instructional models for projectile motion, the application of validity testing represents a crucial aspect to ensure that the product is suitable for educational use. Validity may be viewed in terms of the content and construction of the instructional model; specifically, the extent to which the model accurately represents the physics concept of projectile motion according to the curriculum and is able to facilitate learning effectively. Firstly, subject-matter experts and media experts need to be involved to assess the feasibility of the content (such as alignment of the material, learning indicators, language) and the media-presentation aspects (such as visual design, ease of use) through a dedicated validation sheet. Thus, the process of determining validity in the development of the instructional model for projectile motion encompasses: (1) the development of a validation instrument that covers content, media, and language aspects; (2) the involvement of expert validators to assign scores and offer suggestions for improvement; (3) revision of the product based on the validation results; (4) testing end-user responses to ensure readability and appeal; and (5) determination that the validity score falls within an acceptable category before broad implementation.

Validation Instrument

The validation process was conducted to assess the feasibility and validity of the developed instructional aid. Several validators reviewed the product to evaluate both its instructional content and media quality. This process was intended to ensure that the instructional aid accurately represents the physics concept of projectile motion, aligns with the intended learning indicators, and is appropriate for use in the teaching and learning process. In this sense, validity reflects the extent to which the product functions as intended in facilitating the targeted learning objectives, as described by Hamdani et al. (2024).

The validity instrument covered two main assessment domains, namely content and media. The content aspects assessed included content suitability and conceptual compatibility. The media aspects comprised the suitability of instructional content presentation, tool durability, accuracy, efficiency, student safety, aesthetics, and overall completeness. Together, these aspects provided a comprehensive evaluation of both the pedagogical and technical quality of the instructional aid.

The validators consisted of four expert lecturers from Musamus University, each representing distinct areas of expertise: Physics Education, Teaching Physics, Learning Evaluation, and Educational Technology. In addition, one high school physics teacher from SMA Plus Muhammadiyah Merauke participated as a practitioner validator. The student participants were 18 Grade XI students from SMA Plus Muhammadiyah Merauke in the 2023/2024 academic year, comprising 10 female and 8 male students, all aged between 17 and 18 years.

Teacher and Student Response

Teacher and student response questionnaires were administered to evaluate the effectiveness and practical applicability of the developed instructional aid on the topic of projectile motion. These questionnaires were used to obtain empirical data that go beyond theoretical validity, focusing instead on how the instructional aid functions in real classroom settings.

The teacher response questionnaire was intended to capture information related to teachers' ability and readiness to use the instructional aid during instruction. Through this instrument, the study gathered insights into the actual implementation of the instructional aid in classroom practice, including its clarity, usefulness, and feasibility for supporting teaching activities. The findings from the teacher responses serve as empirical evidence that the instructional aid is not only well designed, but also practical and acceptable for classroom use, which is essential for supporting improvements in student learning outcomes. The teacher questionnaire assessed aspects of content, effectiveness, and attractiveness.

Similarly, the student response questionnaire was designed to collect data from the learners' perspective as the primary users of the instructional aid. This instrument provided empirical evidence regarding students' experiences in using the instructional aid, particularly in terms of understanding the material, learning engagement, and perceived effectiveness. Collecting student responses is crucial to ensure that the instructional aid is not only theoretically feasible but also functionally effective in enhancing learning in the projectile motion topic. The student questionnaire assessed the same core aspects, namely content, effectiveness, and attractiveness.

Likert Scale for Validity and Effectiveness Testing

A Likert scale was used in the validity and effectiveness assessments to convert qualitative judgments into quantitative data. This conversion allows the evaluation results to be measured objectively, compared systematically, and interpreted clearly, making them suitable for further statistical analysis. The use of this scale supports the credibility and accountability of the research instruments, including the instructional aid being evaluated. Table 1 presents the Likert scale conversion applied in this study, where a score of 1 indicates very unsuitable or completely unsuitable, 2 reflects an unacceptable level, 3 represents acceptable quality, and 4 denotes very feasible.

Table 1. Conversion Likert Scale

Score	Qualitative Interpretation
1	Very unsuitable / Completely unsuitable
2	Unacceptable
3	Acceptable
4	Very feasible

Instrument Test

The learning outcome test was employed as the final indicator of instructional productivity, focusing on the actual learning results achieved by students. This test was designed to demonstrate that the developed projectile motion instructional aid is not only feasible and effective based on perceptions, but also capable of producing measurable improvements in students' conceptual understanding and problem-solving abilities. In line with Le et al. (2025), the assessment includes items that vary in number and scope, with several questions addressing multiple skills and content areas simultaneously.

As summarized in Table 2, the test instrument consists of essay-type questions that assess cognitive levels ranging from understanding to evaluation. The items evaluate students' ability to explain the concept of projectile motion, identify initial velocity components along the horizontal and vertical axes, calculate velocities at specific times, determine elevation angles for a given range, and compute total velocity at particular points along the trajectory. In addition, the test includes items that require students to apply special conditions, such as horizontal projectile motion, and to evaluate the influence of gravity on an object's trajectory and velocity. This structure ensures a comprehensive assessment of both conceptual mastery and higher-order thinking related to projectile motion.

Table 2. Test Instrument

Test Item Indicator	Question Format	Cognitive Level
Explain the definition of projectile motion	explanation	C2
Identify the initial velocity components on the x and y axes	explanation	C2
Calculate the velocity on the x axis or y axis after time t	explanation	C3
Determine the elevation angle for a given range	explanation	C4
Calculate the total velocity of the object at a specific point along its trajectory.	explanation	C3
Use special conditions (for example, a horizontal throw from a certain height)	explanation	C4
Evaluate the effect of gravity on the trajectory and velocity of an object.	explanation	C5

Data Analysis

The criteria for the success of the validity and effectiveness testing of the instructional aid stipulate that an average score of at least 61% qualifies the aid as valid and effective. If, upon testing, the score obtained falls below 61%, then revisions and re-implementation are required until the success criterion is met. To determine the level of conceptual understanding of the projectile motion material after instruction with the instructional aid, a learning outcome test comprising 15 items is used. In this study, all students completed this test as part of the end-of-instruction evaluation. The success criterion is clearly defined: student learning outcome scores must be equal to or greater than the minimum competency criterion (MCC) for Physics, namely 70. This means that any student who scores 70 or above is considered to have achieved the expected competence mastery.

The test results are then analyzed quantitatively: first, by calculating the average score of all students; second, by determining the percentage of students who achieve or exceed the score of 70, which serves as an indicator of instructional success. If the percentage of students who reach mastery is still below the target, then follow up actions are necessary, such as remediation or retraining and revision of the instructional method and the instructional aid usage. Thus, the use of the projectile motion instructional aid is evaluated not only through media validity and effectiveness, but also through student learning outcomes that demonstrate real conceptual understanding after instruction. This evaluation provides a comprehensive view of the extent to which the instructional aid supports the teaching objectives and the achievement of projectile motion competency in the Physics learning context.

The guideline for collecting validation data is obtained by aggregating the scores from each validator which consist of the sum of all values given for each aspect and is determined using the following equation.

$$\text{validity score} = \frac{\text{total score}}{\text{maximum score}} \times 100\%$$

The criteria for the score values of validation measurement (Sugiyono, 2017) can be seen in Table 3.

Table 3. Validity Criteria

Criteria	Average value (%)
Very valid	81-100
Valid	61-80
Quite valid	41-60
Invalid	21-40
Very invalid	0-20

The measurement of the effectiveness level of the instructional aid can be determined by using the equation.

$$\text{Response (\%)} = \frac{\text{score}}{\text{total maximum score}} \times 100\%$$

After calculating the percentage of responses, the results are grouped according to the response categories (Table 4) provided by the respondents (Sugiyono, 2017).

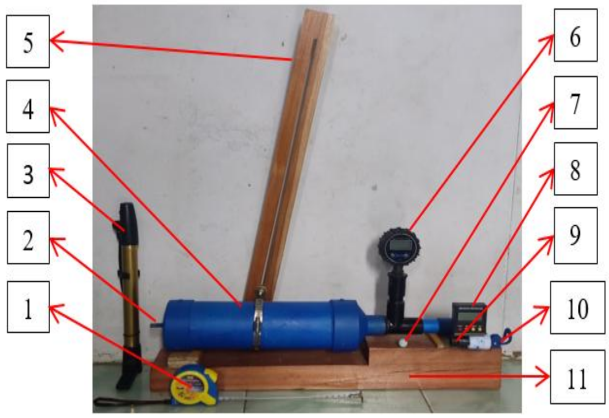
Table 4. Criteria for the effectiveness

Category	Average Value (%)
Very ineffective	0-20
Ineffective	21-40
Quite effective	41-60
Effective	61-80
Very effective	81-100

RESULTS AND DISCUSSION

This research was successfully conducted through a series of systematic stages, beginning with the analysis of problems and needs, followed by the design, development, and finally the pilot testing phase. The product developed was a teaching aid for projectile motion (specifically the parabolic motion), which was then subjected to an in-depth evaluation. The validity of the product was determined through assessment by five validators who ensured that the aspects of content, media, practicality, and instructional suitability were fulfilled. Next, the level of effectiveness of the teaching aid was obtained through a questionnaire administered to one physics teacher and 18 students at SMA PLUS Muhammadyah Merauke, who used the device and provided feedback on its implementation in an authentic learning context.

Furthermore, the study measured students learning outcomes the primary indicator of the products success to determine to what extent the teaching aid positively impacted the understanding of the concept of parabolic motion. Thus, this research did not only focus on the technical creation and validation of the device, but also on its integration into the learning process and its tangible influence on student learning achievement, thereby demonstrating that the teaching aid developed is feasible, effective, and capable of improving learning outcomes in physics instruction, particularly regarding parabolic motion material.



Information
1. Length measuring instrument
2. Venthole
3. Air pump
4. Wind tube
5. Pole
6. Air pressure gauge
7. Marble bullets
8. Angle meter
9. Bullet holder
10. Trigger
11. Base

Figure 3. Parabolic Motion Teaching Aid Product

Based on the experimental results obtained using the parabolic motion teaching aid that was developed, it can be concluded that the elevation angle significantly affects both the maximum range and the maximum height. The experimental results can be seen in Figure 4 and Figure 5 (the detail values for each angle provided in Appendix 1).

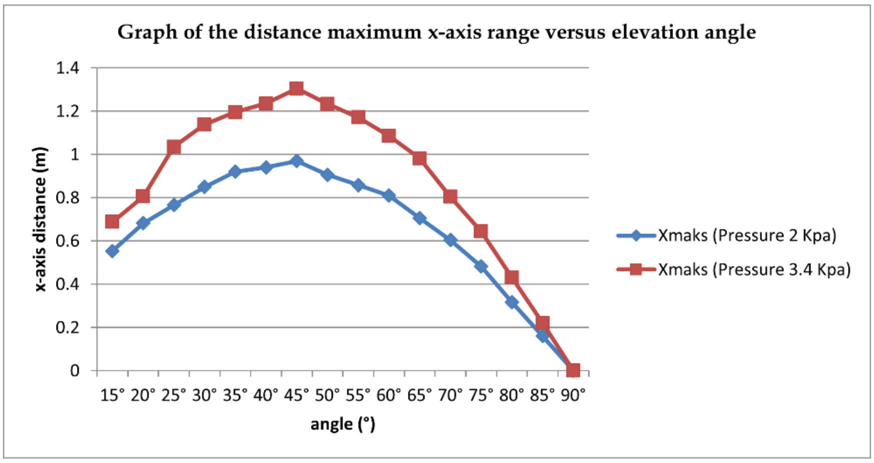


Figure 4. Graph of Distance Maximum (x axis) versus elevation angle

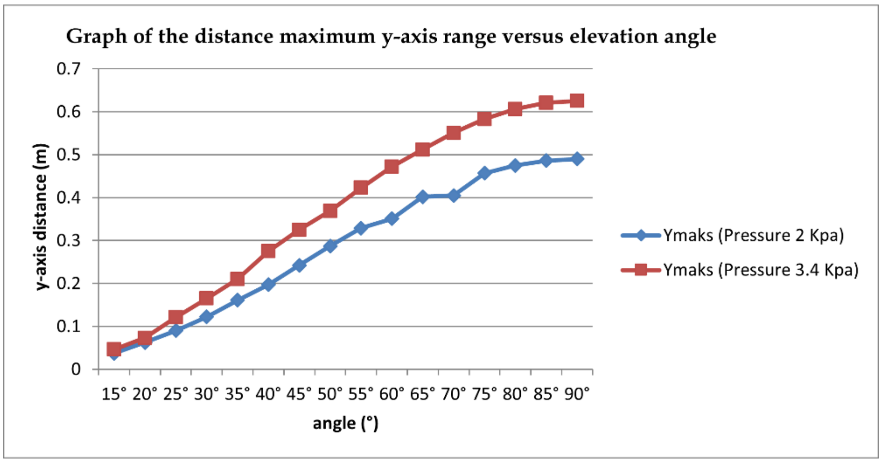


Figure 5. Graph of Distance Maximum (y axis) versus elevation angle

Subsequent calculations were conducted based on data collected to evaluate the accuracy of the teaching aid while taking measurement uncertainty into account. The researcher used experimental data at an angle of 45° and a pressure of 2 kPa. The results of the calculation present in Table 5.

Table 5. Data experiment at an angle of 45° and a pressure of 2 kPa

Experiment	X_i	$X_i - \bar{X}$	$(X_i - \bar{X})^2$
1	0.97	0.006	0.000036
2	0.97	0.006	0.000036
3	1	0.024	0.000576
4	0.98	0.004	0.000016
5	0.96	0.016	0.000256

The measurement uncertainty was calculated using the standard deviation formula based on repeated measurements. The squared deviations of each measurement from the mean were summed, resulting in a total value of 0.00092. This value was then divided by the number of measurements, n = 5, yielding an uncertainty value of 0.000184. Accordingly, the measurement result can be expressed as the mean value plus or minus the uncertainty, written as 0.976 ± 0.000184. This indicates that the true value is expected to lie within this range based on the observed measurement variation.

A parabolic motion apparatus is a tool used to help students understand the concept of projectile motion. Projectile motion is a topic that is often considered quite difficult in physics learning, thus requiring visualization through learning media to support comprehension (Rosita et al., 2020). Therefore, there is a need for media that can effectively explain this concept. An appropriate medium is a teaching aid, which facilitates conceptual understanding through the use of concrete objects. The teaching aid developed by the researcher is designed in accordance with the core and basic competencies of the curriculum, ensuring that the depth of the material aligns with the cognitive level of eleventh grade high school students. This apparatus was developed based on an analysis of the key concepts underlying projectile motion. It illustrates the motion of an object that follows a parabolic trajectory, showing the relationship between the launch angle, the maximum range, and the highest point of the trajectory. From the components of the graphs of range and maximum height, it can be systematically examined how the horizontal distance (x) and maximum height (y) are interrelated through parameters such as initial velocity (v_0), launch angle (θ), and gravitational acceleration (g).

According to classical projectile motion theory, the maximum range is achieved when the launch and landing points are at the same level. In general, the main components and characteristics of this apparatus include an air tube that serves as a source of pressurized air to launch the projectile. The apparatus is also equipped with a pressure gauge to measure the air pressure within the tube and a protractor to accurately measure the launch angle in degrees. An object launched at a certain angle possesses an initial velocity. This initial velocity propels the object to move with a certain height, and the influence of gravity causes the object to follow an elliptical trajectory (Widyastuti, 2021). The concept of projectile motion involves simultaneous analysis of horizontal and vertical vector components, as well as the ability to solve problems related to two dimensional kinematics (Harefa, 2025). Projectile motion can be better understoodwhen students cansee theirconcepts in dimensional views (Pineda, 2020).

Before this parabolic motion teaching aid was used in high school physics learning, a validity test was conducted to ensure that the tool was feasible and effective as a learning medium. The validity assessment involved five expert validators who possessed expertise in physics content and instructional media. The evaluation was based on two main aspects: the material aspect, which assessed the conformity of the physics concepts with the curriculum and the accuracy of theoretical application; and the media aspect, which evaluated the design, safety, ease of use, and attractiveness of the teaching aid for students. Each validator provided assessments, suggestions, and constructive feedback to improve the quality of the developed tool. Based on the evaluation results, an average score of 81.2 out of a maximum of 100 was obtained, indicating a validity percentage of 81% with mean 4.06, median 4.1 and standard deviation 0.41. According to the criteria in Table 3, this value falls within the “Very Valid” category, meaning that the teaching aid meets high scientific and pedagogical standards (see Table 6).

Table 6. Overall Validation Results by Aspect

Aspect	Overall Average Score	Percentage (%)
Material	4.00	81
Media	4.09	

Nevertheless, the analysis results from all validators (Validator I, II, III, IV, and V) also recommended minor revisions in accordance with the provided feedback to ensure that the teaching aid functions more optimally and provides a more interactive, effective, and enjoyable learning experience for high school physics students as presented in Table 7.

Table 7. Results of the Teaching Aid Revision

Before revision	After revision
	
	

This tool enabled students to observe directly how a parabolic trajectory is formed due to the interplay between horizontal and vertical components of motion, thereby significantly improving learning achievement. That instructional models designed with attention to validity, effectiveness, and ease of use not only meet academic standards but also yield positive feedback from users, which contributes greatly to ongoing improvement. Accordingly, the validity of instructional models can be regarded as the result of alignment among the content delivered, the method of delivery, and the learners' response, which collectively enhance the quality of instruction and promote active participation as well as deeper conceptual understanding. The development of valid instructional models necessitates a process of trial implementation, expert evaluation, and user response data analysis to ensure their suitability with the instructional objectives. A teaching aid that is valid means that both its content and design are truly aligned with the concepts intended to be taught (for example, projectile motion: the horizontal component, the vertical component, the trajectory, etc.).

Table 8. Safety description of the teaching aid

Safety Aspect	Potential Hazard	Safety Measures
Maximum Pressure	Air pressure exceeding the limit → components may fail or leak	Restrict operating pressure to a maximum of 4 kPa; install a pressure gauge (manometer) and a pressure relief valve.
Air Leakage	Leaking hose connections → air may jet out, startling the user	Routinely inspect and tighten connections; use hoses and fittings that meet specification requirements
Projectile Direction Control (Parabolic Motion)	The projectile may deviate because of uncontrolled pressure	Ensure the trajectory is safe and does not point at persons; mark a restricted zone in front of the trajectory path.
Student Use	Inattentive handling by students → risk of impact or being stepped on	Provide clear usage instructions; ensure supervision by a teacher.
Maintenance & Inspection	Worn or cracked components → risk of failure during pressurization	Schedule regular audits; replace hoses or fittings that show signs of wear.
Operating Temperature & Environment	Air pressure system or hoses in extreme environments → materials may degrade	Ensure the apparatus is placed in a suitable room, away from direct heat or corrosive chemicals.

Projectile launching is one of these fundamental topics, which involves understanding key concepts such as parabolic trajectory, initial velocity, launch angle, and the influence of gravity (Tuárez-zambrano et al., 2024). If a teaching aid is designed without taking into account the congruence of the underlying concepts, then its pedagogical function will be weak. Developmental studies show that validation by content and media experts serves as a benchmark to ensure that the aid is genuinely tied to the instructional material (Febrianti & Prabowo, 2021). Thus, it can be concluded that the more valid the teaching aid is, the greater the likelihood that learners will accurately observe and comprehend the concept which constitutes a prerequisite for successful development of the aid. During the operation of the apparatus, users are obliged to ensure that the pressure does not exceed 4 kPa and that the manometer is functioning correctly. The launch trajectory must be cleared of unauthorized persons, and both operators and observers must position themselves outside the projectile's flight path. Restraint from modifying the system in ways that increase the pressure load or extend components without technical evaluation also constitutes a moral responsibility toward collective safety. Thus, the user ethics not only pertain to adherence to instructions, but also to preventing potential hazards (see Table 8) arising from experiments that exceed safe limits. After each launch, the recovery procedure should be performed systematically the pressure must be reduced to zero, connections should be safely disconnected, and all parts of the apparatus inspected for signs of cracking, wear or leakage.

In physics instruction, the use of an air pressure based projectile launcher to demonstrate projectile motion offers a concrete bridge between theory and practical application. The teacher begins by outlining the fundamental concepts of projectile motion, including its horizontal and vertical components, as well as the role of air pressure as the initial propulsive force, which must not exceed 4 kPa in accordance with the maximum safe capacity of the pressure tank. After this theoretical introduction, a demonstration is carried out by launching the projectile through an air nozzle at various elevation angles, while recording the distance traveled and the trajectory shape. Students are then organized into small groups and given the opportunity to conduct their own experiments, manipulating both the elevation angle and the air pressure, and measuring parameters such as horizontal range, maximum height, and flight time (see Figure 6).

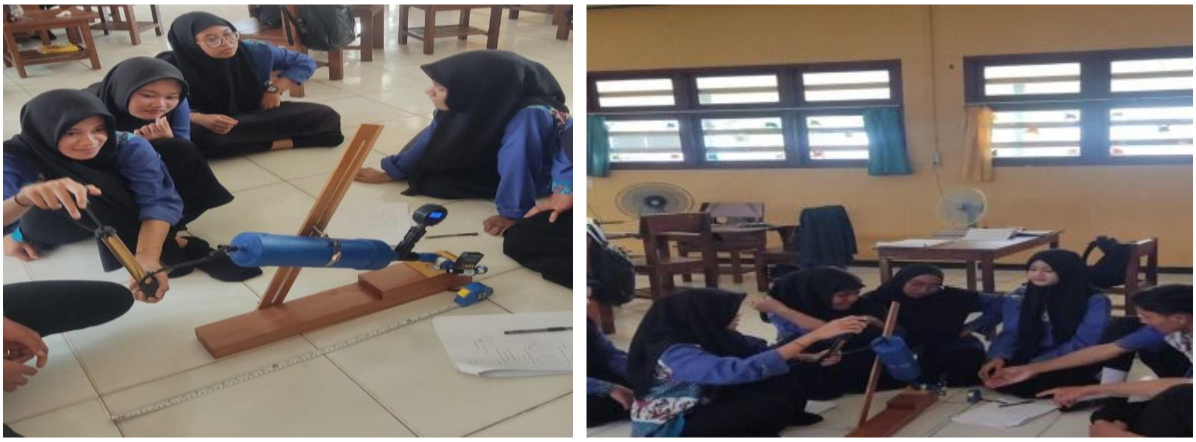


Figure 6. The use of a teaching aid for parabolic motion in learning

The collected data are subsequently analyzed by the students they plot the trajectories, calculate the initial velocity, and compare their empirical findings with theoretical predictions. A class discussion is facilitated to explore the factors influencing the experimental outcomes, such as angle, pressure, and possible air resistance, and to assess to what extent the results align with or deviate from the idealized model of projectile motion. Safety procedures are integral to this setup: the pressure tank must be equipped with a pressure gauge and a regulator to prevent over pressurization, and routine leak checks must be performed prior to each launch. Moreover, the launch area must be arranged to ensure no person or object lies in the flight path, and ideally be equipped with a backstop wall if necessary. Full personal protective equipment including safety goggles is mandatory for all participants. After the experiment, a reflection session is held in which students evaluate both the safety and the accuracy of their data, identify potential hazards encountered, and propose mitigation strategies. There were significant changes in academic performances of students taught with instructional aids compared with students not opportune to be taught with the materials (Adebayo, 2018).

A limited trial of the teaching aid was conducted after the tool was declared valid by both media and content experts, with a minimum validity criterion ranging from 60 % to 100 %. The limited trial was then implemented with 18 students of Class XI at SMA PLUS Muhammadyah Merauke, who completed response questionnaires. The questionnaires for both teachers and students were intended to evaluate the effectiveness of the developed product. Data from the teacher response questionnaire indicated an average score of 43 with a percentage of 86 % with mean 4.3 and standard deviation 0.675, categorizing the trial of the teaching aid as very effective. Meanwhile, the student response questionnaire yielded an average score of 56.72 with a percentage of 76 % with mean 3.7815 and standard deviation 0.1786, classifying the trial as effective according to the applied criteria. The questionnaires were completed after the participants observed and utilized the teaching aid being tested. Thus, this response data provides empirical evidence that the teaching aid is not only theoretically valid but also practically effective in its application for both students and teachers. The high percentage, particularly among teachers, indicates that the teaching aid meets the criteria for practicality and user acceptance, which are essential for the successful development of teaching aids. Therefore, the sequential process of expert validation, followed by limited trials and evaluation of user responses, constitutes an integrated approach to ensure that the developed teaching aid is not only construct valid but also functions effectively within the actual learning environment. Evaluating the effectiveness of an instructional device helps in determining whether the desired learning outcomes are achieved (Jan & San, 2025).

The effectiveness of a teaching aid in the instruction of projectile motion is a key indicator of the success of the media development process. When the teaching aid meets the validity criteria and is subsequently subjected to a limited trial, positive results indicate that the media is indeed capable of supporting the learning process in practice. Studies utilizing interactive simulations have shown an increase in students conceptual understanding following the use of an effective teaching aid for projectile motion (Mohamad, 2025). Thus, effectiveness is directly related to the extent to which the teaching aid can: (1) help students visualize and manipulate the components of projectile motion (such as horizontal and vertical components and the trajectory), (2) reduce common misconceptions associated with this material, and (3) improve learning outcomes or scientific process skills. For instance, if students demonstrate a medium to high N-gain after using the teaching aid, it can be categorized as effective. Effectiveness also influences students' motivation and active participation in laboratory activities and discussions, which, in turn, supports deeper understanding.

Therefore, in the development of a projectile motion teaching aid, researchers must not only ensure the validity of the design and content but also evaluate effectiveness through actual trials, assessment of learning outcomes, and collection of user feedback. Effectiveness thus serves as a bridge between a teaching aid that is well designed on paper and one that functions effectively in practice within the context of physics learning on projectile motion.

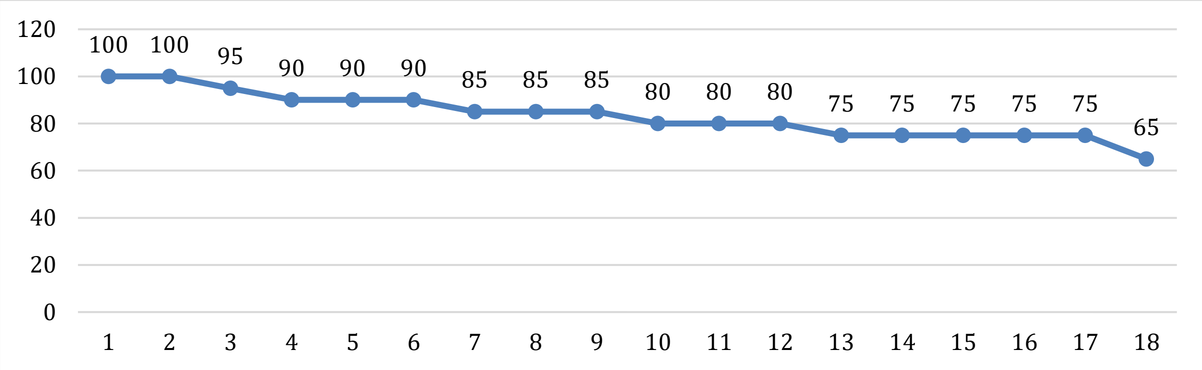


Figure 7. Students' learning outcomes

Figure 7 shows that one student achieved a score of 65, which means they did not reach the school's established Minimum Competency Standard (KKM). On the other hand, the remaining 17 students obtained scores between 75 and 100, thereby meeting or exceeding the KKM. From these data it can be concluded that the vast majority of the learners demonstrated very good achievement namely 17 out of 18 students (approximately 94 %) passed the standard with mean 83,88, median 80 and standard deviation 8.09. Teachers can also provide questions to evaluate students' understanding at the end of the lesson and at the end of a course or lecture (Sirait et al., 2017). Answering a question correctly must be accompanied by good mastery tosolve the given problem (Sulman et al., 2023). This situation reflects that the instructional practices implemented to date have effectively reached most students, supporting the attainment of fundamental competencies in line with the target.

However, one student is still below the threshold this indicates the need for more specific intervention or follow up to optimize his/her learning result. Learner results are said to be achieved if they experience the development and improvement of behavior expected in the formulation of learning objectives (Megasafitri, 2023). Mastering physics today involves more than just memorizing formulas; it also requires interactive and visual learning (Meka Jane C, 2025). Students interest to participating in the learning process showed their will to understand what they learn (Tanti, 2025). Such follow up may include remedial teaching, supplementary tutoring, or a reassessment to identify the specific barrier (for example, conceptual understanding, learning motivation, or learning strategy) that caused the score to fall short. In the teaching and learning process, the teacher has a duty to deliver material as well as to develop the topics of the learning in order to provide optimum learning outcomes (Umar & Abdjul, 2022).

Thus, although overall the performance of this class is considered very good, attention to the student who has not yet reached mastery remains necessary so that all learners can achieve competency equitably and no student is left behind. In physics learning, teachers require appropriate media to facilitate the delivery of teaching materials, such as in the topic of projectile motion, so that students can follow the lessons easily and efficiently (Rosita et al., 2020). Learning outcomes in education are proofs that a person succeedsin pursuing a teaching and learning process which theoretically provides a distinctive style for students to internalize and practice their knowledge in accordance with the abilities they acquire (Hatiku et al., 2022).

The use of instructional models in teaching the topic of projectile motion contributes significantly to improved student learning outcomes. As found in the study "The Experimental Study of Kinesthetic Style Student Learning Outcomes in Remedial Teaching Assisted by Projectile Motion Props," students with a kinesthetic learning style who used projectile motion props achieved a normalized gain of 0.64 in the cognitive domain of understanding (C2), compared to only 0.50 in the control group (Putri & Suwarna, 2020). This result indicates that the props facilitate a more concrete and visual comprehension of projectile motion concepts, thus reducing the abstraction barriers often encountered in kinematics. Consequently, student learning outcomes in terms of conceptual mastery and competence achievement increase when the instruction is supplemented with concrete media that allow active exploration of projectile motion.

However, it is important to note that the effectiveness of such props is also influenced by factors such as the alignment of the props with students' learning styles, the instructional quality of their usage, and their systematic integration within the teaching process. Therefore, to optimize the observed gains in learning outcomes, educators should carefully design instruction that utilises appropriate props, provide opportunities for direct student exploration, and conduct suitable evaluations and follow up. With this approach, the use of props for the concept of projectile motion can become an effective strategy to promote higher and more equitable learning outcomes across all learners. These aid can show the characteristics of the projectile motion. Besides, the aid can present the phenomenon of projectile motion in more real terms students can understand the concept better, such as it is easier to visualize the trajectory of the movement of objects after being given the initial angle while students in the controlled group understood the concept of projectile motion verbally (Putri & Suwarna, 2020). Students are not presented with a phenomenon that can visualize projectile motion in real terms, so it is less effective in understanding the concept. Students need to be fully involved in every aspect of learning, both in experiments and in other tasks, to maximize their understanding of the material and exam results. Active participation can be the key to ensuring that students not only remember the material, but also truly understand it, which in turn will improve their overall learning outcomes (Irsalina, 2025). Support from various parties, innovation in teaching methods, and collaboration between education professionals can bring better education and be relevant to the demands of the times (Durasa, 2024).

CONCLUSION

The development of an air pressure based projectile launcher as a teaching aid for the parabola motion topic in senior high school physics has met the criteria of validity and effectiveness to a very high degree. The validity test conducted by media and material experts resulted in the very valid category, indicating that the aspects of construction, content, and appearance of the device exhibit a high level of feasibility for its use as a physics learning medium. Teacher responses fell into the very effective category, while student responses were categorized as effective, demonstrating that the teaching aid is well accepted and usable in actual instructional settings. Moreover, the learning achievement indicator shows that 94 % of students passed the Minimum Competency Criteria (KKM) on the parabola motion material, based on the learning outcomes obtained it can be concluded that this air pressure-based teaching aid for projectile motion is well accepted.

RECOMMENDATION

Schools and teachers should integrate the teaching aid routinely into physics instruction especially when covering projectile motion so that students gain concrete experiences that support conceptual understanding and improve learning outcomes.

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Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Mitra Rahayu	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓
Jeffri Parrangan	✓	✓	✓			✓		✓	✓	✓	✓	✓		✓
Ihang Ramadhan A.	✓	✓		✓			✓	✓	✓	✓	✓		✓	✓

Conflict of Interest Statement
Authors state no conflict of interest.

Informed Consent
The protection of participants privacy was strictly observed in this study. Written informed consent was obtained from all individuals prior to their inclusion in the research. All procedures involving human participants were conducted in accordance with ethical standards**.** We have obtained informed consent from all individuals included in this study.

Ethical Approval
This research was conducted in accordance with the principles of research ethics and academic integrity. All research procedures complied with applicable national regulations and relevant institutional policies. Informed consent was obtained from all participants prior to their involvement in the study. Participants privacy and data confidentiality were strictly protected, and all research data were managed responsibly and used solely for scientific purposes.

Data Availability
The data resulting from this study are entirely derived from original research conducted by the authors research team.

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Appendix 1

Result measurement of the parabolic motion aid

Angle (°)	Pressure 2kPa		Pressure 3.4 kPa	
	$\bar{X}$ (m)	Y_{maks} (m)	$\bar{X}$ (m)	Y_{maks} (m)
15	0.554	0.037	0.688	0.046
20	0.682	0.062	0.806	0.073
25	0.766	0.09	1.036	0.121
30	0.85	0.122	1.138	0.165
35	0.92	0.161	1.196	0.21
40	0.94	0.197	1.236	0.275
45	0.97	0.242	1.304	0.325
50	0.906	0.287	1.234	0.369
55	0.858	0.329	1.172	0.423
60	0.81	0.351	1.086	0.472
65	0.706	0.402	0.982	0.512
70	0.604	0.405	0.804	0.551
75	0.482	0.457	0.644	0.583
80	0.318	0.475	0.432	0.606
85	0.16	0.486	0.22	0.621
90	0	0.49	0	1.625