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Promoting Analytical Thinking in Physics Learning: The Integration of a Scientific Approach and Flying Water Apparatus in Projectile Motion Instruction

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ABSTRACT

Purpose of the study: This study aimed to investigate the effect of a Scientific Approach assisted by the Flying Water Apparatus on students' analytical skills in projectile motion learning, specifically examining whether integrating inquiry-oriented activities with a physical visualization tool could effectively enhance students' analytical thinking abilities.

Methodology: This study employed a quasi-experimental design using a non-equivalent control group design. Participants consisted of Grade 10 science students at Madrasah Aliyah Universitas Islam Negeri Syarif Hidayatullah Jakarta selected through purposive sampling. Data were collected using an analytical skills test and a Student Response Questionnaire. Statistical analyses included Shapiro–Wilk normality tests, Levene's and Bartlett's homogeneity tests, Mann–Whitney U tests, independent-samples t-tests, and N-gain analysis.

Main Findings: The experimental group achieved a higher posttest mean score (6.21) than the control group (4.57). Statistical analysis revealed a significant difference between groups ($p = 0.001$). The experimental group obtained a medium N-gain score (0.60), while the control group achieved a low N-gain score (0.23). The findings indicate that the scientific approach assisted by the Flying Water Apparatus significantly improved students' analytical skills in projectile motion learning.

Novelty/Originality of this study: This study integrates the Scientific Approach and a low-cost Flying Water Apparatus within a single instructional intervention to enhance analytical skills in projectile motion learning. Unlike previous studies that focused on conceptual understanding or learning achievement, this research specifically examines analytical skills based on the dimensions of differentiating, organizing, and attributing, thereby extending evidence regarding inquiry-based physics instruction and higher-order thinking development.

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1. INTRODUCTION

Developing analytical thinking has become a central objective of science education because modern societies increasingly require individuals who can evaluate evidence, solve complex problems, and make informed decisions in scientific and technological contexts. Research indicates that analytical thinking constitutes a fundamental component of higher-order thinking skills and significantly contributes to scientific literacy, problem-solving ability, and academic achievement in science learning [1]-[3]. Students who possess strong analytical skills are generally better able to interpret scientific information, recognize causal relationships, and construct evidence-based explanations of natural phenomena [4]-[6]. Despite its recognized importance, many educational systems continue to report difficulties in fostering analytical reasoning among secondary-school students, particularly within science-related disciplines [7]-[9]. Consequently, enhancing analytical thinking remains an important challenge and priority for researchers, educators, and policymakers worldwide.

Physics education provides a unique environment for developing analytical thinking because students are required to connect mathematical representations, conceptual explanations, experimental observations, and real-world phenomena into coherent scientific understanding. According to the revised Bloom's taxonomy, analytical thinking involves differentiating, organizing, and attributing information, all of which are essential cognitive processes for understanding complex physical systems [10]-[12]. Recent studies have shown that students often struggle to transfer conceptual knowledge into analytical reasoning when solving physics problems, particularly those involving multiple variables and dynamic interactions [13]-[15]. Such difficulties can negatively affect students' conceptual understanding, scientific reasoning, and overall learning performance [16]-[18]. Therefore, instructional strategies capable of promoting analytical thinking have become increasingly important in contemporary physics education research.

Among various physics topics taught at the secondary-school level, projectile motion is frequently reported as one of the most difficult concepts because it requires students to simultaneously understand horizontal and vertical motion components within a two-dimensional framework. Previous studies have demonstrated that many students hold misconceptions regarding projectile trajectories, velocity components, and acceleration, leading to difficulties in analyzing motion quantitatively and conceptually [19]-[21]. These learning challenges are often exacerbated when instruction relies predominantly on mathematical derivations and teacher-centered explanations without sufficient opportunities for observation and experimentation. Consequently, students tend to memorize equations rather than develop meaningful conceptual understanding and analytical reasoning. Such conditions highlight the necessity of designing more engaging and inquiry-oriented learning environments for teaching projectile motion.

Contemporary educational theories emphasize that meaningful learning occurs when students actively construct knowledge through observation, questioning, investigation, reasoning, and communication rather than passively receiving information from teachers. The scientific approach aligns with constructivist learning principles by encouraging students to engage in systematic inquiry processes that resemble authentic scientific investigations [22]-[24]. Through activities such as observing phenomena, generating questions, collecting evidence, analyzing data, and communicating findings, students are expected to develop deeper conceptual understanding and stronger analytical abilities [25]-[27]. Empirical evidence has demonstrated that inquiry-oriented and scientific learning approaches can significantly improve students' critical thinking, reasoning, and academic performance in science subjects [25]-[29]. Therefore, the scientific approach offers considerable potential for enhancing analytical skills in physics learning contexts.

Besides instructional approaches, learning media play an essential role in facilitating students' understanding of abstract scientific concepts by transforming invisible or complex phenomena into observable and meaningful experiences. Research in physics education consistently shows that physical teaching aids and experimental apparatus can improve conceptual understanding, student engagement, and higher-order thinking by connecting theoretical knowledge with direct observation [30]-[32]. Visualization tools are particularly important in projectile motion learning because students often experience difficulty relating mathematical equations to actual motion trajectories [33], [34]. Through direct interaction with observable phenomena, students can more effectively identify patterns, compare variables, and formulate scientific explanations. Consequently, the integration of teaching aids into inquiry-based learning environments may provide significant benefits for developing analytical skills.

Although previous studies have reported positive impacts of scientific approaches, inquiry-based learning, and physics teaching aids on students' learning outcomes, the majority of these investigations have focused primarily on conceptual understanding, achievement scores, or scientific attitudes rather than analytical thinking skills. Furthermore, research concerning projectile motion frequently examines digital simulations and computer-based visualizations, while relatively little attention has been devoted to the use of low-cost physical apparatus designed to support analytical reasoning through direct observation and experimentation. Existing literature also provides limited evidence regarding the combined implementation of a scientific approach and a specialized projectile-motion teaching aid within a single instructional intervention. Therefore, an important empirical gap remains concerning how such integration may influence students' analytical skills. This study addresses this gap through the use of a Flying Water apparatus integrated with a scientific approach in projectile-motion learning.

Based on the identified theoretical and empirical gaps, this study aims to investigate the effect of a scientific approach assisted by a Flying Water teaching apparatus on students' analytical skills in learning projectile motion. Specifically, the study examines whether the integration of inquiry-oriented learning activities and a physical visualization tool can enhance students' ability to differentiate, organize, and attribute scientific information during problem-solving processes. The findings are expected to provide empirical evidence regarding the effectiveness of combining scientific inquiry and low-cost experimental media for developing higher-order thinking skills in physics education. In addition, this study contributes to the growing body of research on analytical thinking by focusing specifically on projectile motion, a topic widely recognized as conceptually challenging. Ultimately, the study may offer practical recommendations for teachers seeking accessible and effective strategies to improve analytical reasoning in secondary-school physics classrooms.

2. RESEARCH METHOD

2.1. Research Design

This study employed a quasi-experimental research design using a non-equivalent control group design. Two intact classes were assigned as the experimental and control groups because random assignment of students was not feasible within the school setting [35]-[37]. Both groups completed a pretest before the intervention and a posttest after the intervention to evaluate changes in students' analytical skills regarding projectile motion concepts. The experimental group received instruction through a scientific approach assisted by the Flying Water apparatus, whereas the control group received conventional instruction.

The independent variable was the implementation of the Scientific Approach assisted by the Flying Water Apparatus. The dependent variable was students' analytical skills in projectile motion. Analytical skills were operationalized according to the cognitive-analysis dimension (C4) of the revised Bloom's taxonomy, including differentiating, organizing, and attributing.

The instructional treatment was implemented through the five stages of the Scientific Approach: observing, questioning, experimenting, associating, and communicating. During the intervention, students in the experimental group used the Flying Water Apparatus to investigate projectile trajectories and analyze relationships among launch angle, maximum height, and horizontal range. Students were encouraged to formulate hypotheses, collect observational data, interpret experimental results, and communicate their findings. In contrast, students in the control group received teacher-centered instruction through explanation and problem-solving activities.

3.2. Participants

The study was conducted during the first semester of the 2025–2026 academic year at MA Pembangunan UIN Jakarta, an Islamic senior high school in Jakarta, Indonesia. The target population consisted of all Grade 10 science-track students enrolled in the school. Participants were selected using purposive sampling to ensure comparable academic characteristics between groups. One class was assigned as the experimental group and another as the control group. The selection was based on recommendations from physics teachers and similarities in prior academic achievement.

3.3. Research Instruments

The primary instrument was an Analytical Skills Test consisting of multiple-choice items developed according to Anderson and Krathwohl's revised Bloom's taxonomy. The instrument assessed three analytical dimensions: differentiating, organizing, and attributing. The test focused on projectile motion concepts, including motion variables, launch angle, maximum height, and horizontal displacement.

In addition, a Student Response Questionnaire was administered to evaluate students' perceptions of the learning experience and the use of the Flying Water Apparatus.

Table 1. Blueprint of the Analytical Skills Test

Learning Objective	Analytical Skill Dimension	Indicator	Projectile Motion Concept	Item No.
Identify variables involved in projectile motion	Differentiating	Distinguish between horizontal and vertical motion variables	Initial velocity, angle, displacement	1
Determine physical quantities in projectile motion	Differentiating	Differentiate relevant and irrelevant information for problem solving	Velocity components	2
Determine physical quantities in projectile motion	Organizing	Organize relationships among variables and equations	Horizontal motion equations	3
Analyze the effect of	Differentiating	Compare changes in maximum	Maximum height	4

Learning Objective	Analytical Skill Dimension	Indicator	Projectile Motion Concept	Item No.
launch angle on maximum height		height under different launch angles		
Determine physical quantities in projectile motion	Organizing	Arrange mathematical relationships among motion variables	Vertical motion equations	5
Determine physical quantities in projectile motion	Attributing	Identify underlying principles governing projectile motion	Gravitational acceleration	6
Determine physical quantities in projectile motion	Attributing	Infer causes of variation in projectile trajectories	Velocity and angle relationship	7
Identify variables involved in projectile motion	Organizing	Classify motion parameters based on their functions	Motion components	8
Analyze the effect of launch angle on horizontal range	Differentiating	Compare trajectory outcomes for different launch angles	Horizontal range	9
Analyze the effect of launch angle on maximum height	Organizing	Explain relationships among angle, velocity, and height	Maximum height analysis	10
Analyze the effect of launch angle on horizontal range	Organizing	Interpret relationships among variables affecting range	Range analysis	11
Analyze the effect of launch angle on maximum height	Attributing	Draw conclusions based on observed motion patterns	Maximum height interpretation	12
Analyze the effect of launch angle on horizontal range	Attributing	Explain causal factors influencing projectile distance	Range interpretation	13
Identify variables involved in projectile motion	Attributing	Infer motion characteristics from given evidence	Projectile characteristics	14

Table 2. Distribution of Items Across Analytical Skill Dimensions

Analytical Skill Dimension	Indicator Description	Number of Items	Percentage (%)
Differentiating	Distinguishing relevant information, variables, and motion characteristics	5	35.7
Organizing	Structuring relationships among concepts, equations, and variables	5	35.7
Attributing	Identifying causes, drawing conclusions, and explaining phenomena	4	28.6
Total		14	100

Table 3. Analytical Skills Operational Definition

Dimension	Operational Definition	Expected Student Performance
Differentiating	Ability to distinguish relevant information, variables, and representations in projectile motion problems	Identify known and unknown quantities and separate horizontal and vertical motion components
Organizing	Ability to structure relationships among concepts, equations, and variables	Connect projectile motion variables and formulate appropriate solution strategies
Attributing	Ability to infer causes, explain patterns, and draw conclusions from observations	Explain how launch angle influences maximum height and horizontal range

Prior to implementation, all instruments underwent expert review and pilot testing. Item validity was examined using Pearson Product–Moment Correlation, while reliability was evaluated using the Kuder–Richardson Formula 20 (KR-20). Only valid and reliable items were retained for the final data collection process.

3.4. Data Collection Procedure

Data collection was conducted in three phases: preparation, implementation, and post-intervention analysis. During the preparation phase, instructional materials, lesson plans, research instruments, and the Flying Water Apparatus were developed and validated. The implementation phase included pretesting, instructional treatment, and posttesting. The final phase involved statistical analysis and interpretation of the results.

3.8. Data Analysis

Data were analyzed using both descriptive and inferential statistics. Descriptive statistics were used to summarize students' analytical skills before and after the intervention. Inferential statistics included normality testing, homogeneity testing, and hypothesis testing to determine the effectiveness of the Scientific Approach assisted by the Flying Water Apparatus. Statistical significance was established at $\alpha = 0.05$.

3. RESULTS AND DISCUSSION

3.1. Baseline Analytical Skills Before the Intervention

Before the intervention, a pretest was administered to determine whether the experimental and control groups possessed comparable analytical skills in projectile motion. The descriptive statistics revealed that both groups demonstrated relatively low initial performance. The experimental group obtained a mean score of 2.50, whereas the control group achieved a slightly higher mean score of 2.85 out of a maximum score of 9.00. The small difference between the two means suggests that both groups began the study with similar levels of analytical skills.

Table 4. Pretest Descriptive Statistics

Group	Mean Score	Maximum Possible Score
Experimental Group	2.50	9.00
Control Group	2.85	9.00

The normality analysis using the Shapiro–Wilk test indicated that the pretest scores of both groups were not normally distributed. The significance values obtained for the experimental and control groups were 0.033 and 0.008, respectively, both of which were below the significance threshold of 0.05. Therefore, the assumption of normality was not satisfied for the pretest dataset.

Table 5. Normality Test Results for Pretest Scores

Group	Shapiro–Wilk Sig.	Decision
Experimental Group	0.033	Non-normal
Control Group	0.008	Non-normal

Since the pretest scores were not normally distributed, homogeneity was examined using Levene's test. The analysis produced a significance value of 0.536, which exceeded the threshold of 0.05. Consequently, the variance of the two groups was considered homogeneous.

Table 6. Homogeneity Test of Pretest Scores

Statistic	Value
Levene's Sig.	0.536
α	0.05

Because the normality assumption was violated, a Mann–Whitney U test was conducted to examine differences between the experimental and control groups before the intervention. The analysis yielded an Asymptotic Significance value of 0.247, which was greater than 0.05. Therefore, no statistically significant difference was observed between the two groups at the beginning of the study. This finding indicates that the experimental and control groups were equivalent in terms of analytical skills prior to the instructional treatment.

Table 7. Mann–Whitney U Test for Pretest Scores

Statistic	**Value**
Asymp. Sig. (2-tailed)	0.247
α	0.05
Decision	No Significant Differen

The pretest findings demonstrate that both groups possessed similarly low analytical skills before the intervention. Statistical analysis confirmed that there was no significant difference between the experimental and control groups ($p = 0.247$), indicating equivalent baseline conditions. Therefore, any differences observed during the posttest phase can be more confidently attributed to the instructional intervention rather than pre-existing differences in analytical ability.

3.2. Posttest Performance and Treatment Effect

Following the instructional intervention, students in both groups demonstrated improvements in analytical skills. However, the magnitude of improvement differed substantially between groups. The experimental group, which learned through the Scientific Approach assisted by the Flying Water Apparatus, achieved a mean posttest score of 6.21. In contrast, the control group, which received conventional instruction, obtained a mean score of 4.57. These findings indicate that students exposed to the intervention achieved higher analytical-skill performance than those in the control group.

Table 6. Posttest Descriptive Statistics

Group	Mean Pretest	Mean Posttest	Mean Difference
Experimental Group	2.50	6.21	3.71
Control Group	2.85	4.57	1.72

The normality analysis revealed that posttest scores in both groups were normally distributed. The Shapiro–Wilk significance values were 0.267 for the experimental group and 0.058 for the control group. Since both values exceeded the significance criterion of 0.05, the assumption of normality was satisfied. Therefore, parametric statistical procedures could be employed for subsequent analyses.

Table 7. Normality Test Results for Posttest Scores

Group	Shapiro–Wilk Sig.	Decision
Experimental Group	0.267	Normal
Control Group	0.058	Normal

To evaluate equality of variances between groups, Bartlett's homogeneity test was performed. The analysis produced a significance value of 0.918, which was substantially greater than the significance level of 0.05. Therefore, the variances of the two groups were considered homogeneous, fulfilling another assumption required for independent-samples t-testing.

Table 8. Homogeneity Test Results for Posttest Scores

Statistic	Value
Bartlett Sig.	0.918
α	0.05
Decision	Homogeneou

An independent-samples t-test was conducted to determine whether the observed difference in posttest performance between the experimental and control groups was statistically significant. The analysis yielded a significance value of 0.001, which was lower than the significance level of 0.05. Therefore, the null hypothesis was rejected and the alternative hypothesis was accepted. These results indicate that the Scientific Approach assisted by the Flying Water Apparatus had a significant positive effect on students' analytical skills in projectile motion learning.

Table 9. Independent-Samples t-Test Results

Statistic	Value
Sig. (2-tailed)	0.001
α	0.05
Decision	Significant Difference
Conclusion	H_0 Rejecte

The posttest findings provide strong evidence that integrating the Scientific Approach with the Flying Water Apparatus enhanced students' analytical skills more effectively than conventional instruction. Students in the experimental group achieved an average score increase of 3.71 points, whereas students in the control group improved by only 1.72 points. Furthermore, the statistically significant difference observed between groups ($p = 0.001$) confirms that the intervention contributed substantially to students' learning outcomes. These findings suggest that combining inquiry-oriented learning activities with concrete physical demonstrations can facilitate deeper conceptual understanding and strengthen analytical reasoning in projectile motion.

To evaluate learning improvement more comprehensively, normalized gain (N-gain) analysis was conducted. The results revealed that students in the experimental group achieved a mean N-gain score of 0.60, which falls within the medium category. Conversely, the control group obtained an N-gain score of 0.23, corresponding to the low category. These findings indicate that the intervention produced a substantially greater improvement in analytical skills than conventional instruction.

Table 10. Comparison of N-Gain Scores

Group	N-Gain	Category
Experimental Group	0.60	Medium
Control Group	0.23	Low

The N-gain results demonstrate that the Scientific Approach assisted by the Flying Water Apparatus not only improved students' posttest performance but also produced a higher rate of learning improvement. While the control group exhibited limited progress, students in the experimental group experienced moderate improvement according to the established N-gain criteria. This pattern suggests that the intervention was effective in promoting meaningful learning and analytical-skill development throughout the instructional process.

The findings of this study demonstrate that the Scientific Approach assisted by the Flying Water Apparatus significantly enhanced students' analytical skills in projectile motion learning, as evidenced by the higher posttest mean score (6.21) and medium N-gain category (0.60) achieved by the experimental group. These findings are consistent with previous studies reporting that inquiry-based learning environments promote scientific reasoning, analytical thinking, and science literacy by actively engaging students in observation, experimentation, evidence evaluation, and conclusion-making processes. For instance, Kang [38] found that inquiry-based learning positively contributes to science literacy when supported by high instructional quality, while Wang et al. [39] reported that structured inquiry activities significantly improve students' scientific and mathematical literacy. Similarly, Ješková et al. [40] demonstrated that active learning strategies grounded in inquiry-based science education effectively develop students' inquiry skills and higher-order cognitive abilities. The present study extends these findings by showing that inquiry-oriented learning supported by direct physical experimentation can significantly strengthen analytical skills in the context of projectile motion, a topic that is often considered conceptually challenging in physics education.

A major contribution of this study lies in its novelty. Previous investigations have generally examined either the effectiveness of the Scientific Approach or the impact of physics teaching aids separately. In contrast, this study integrated both components within a single instructional intervention through the use of the Flying Water Apparatus to support the learning of projectile motion. Furthermore, while many previous studies focused primarily on learning achievement, conceptual understanding, or critical thinking, the present study specifically investigated analytical skills based on Anderson and Krathwohl's analytical dimensions, namely differentiating, organizing, and attributing. Another distinctive contribution is the utilization of a low-cost and easily replicable experimental apparatus that enables students to directly observe projectile trajectories and relationships among physical variables. Therefore, this study extends existing literature by providing empirical evidence regarding how the integration of inquiry-oriented pedagogy and concrete experimental media contributes to the development of analytical skills in physics learning.

The results also provide important implications for educational practice and physics instruction. The findings suggest that analytical skills can be enhanced when students are actively involved in scientific investigations rather than merely receiving information through teacher-centered explanations. The use of the Flying Water Apparatus allowed students to visualize projectile motion, formulate hypotheses, collect evidence, analyze relationships among variables, and communicate their findings. Such learning experiences align with constructivist principles, which emphasize that knowledge is developed through active engagement with phenomena and evidence. Consequently, physics teachers may consider integrating low-cost experimental media with inquiry-based instructional approaches to promote higher-order thinking skills, particularly in topics that are conceptually abstract and mathematically demanding. These implications are especially relevant for schools with limited laboratory facilities because the apparatus used in this study can be implemented with relatively simple resources.

Although the findings demonstrate positive effects, several limitations should be acknowledged when interpreting and generalizing the results. First, the study involved a relatively small sample drawn from a single educational institution, which may limit the generalizability of the findings to broader educational contexts. Second, the intervention was implemented only within the topic of projectile motion; therefore, the effectiveness of the approach for other physics topics remains uncertain. Third, the assessment focused exclusively on analytical skills and did not investigate other higher-order cognitive outcomes such as critical thinking, problem-solving ability, or scientific creativity. Future studies should involve larger and more diverse samples, incorporate multiple schools, and examine the long-term effects of integrating scientific inquiry with experimental media across different scientific domains. Such investigations would strengthen the external validity of the findings and provide a more comprehensive understanding of how inquiry-oriented instructional interventions contribute to students' higher-order thinking development.

4. CONCLUSION

This study concludes that the implementation of the Scientific Approach assisted by the Flying Water Apparatus significantly improves students' analytical skills in learning projectile motion. Prior to the intervention, both the experimental and control groups demonstrated comparable analytical abilities, as indicated by the absence of a significant difference in pretest scores ($p = 0.247$). After the intervention, the experimental group achieved a substantially higher mean posttest score (6.21) than the control group (4.57), with the independent-samples t-test revealing a significant difference between the groups ($p = 0.001$). Furthermore, the experimental group attained a medium N-gain score (0.60), while the control group achieved only a low N-gain score (0.23), indicating a greater rate of learning improvement. These findings demonstrate that integrating inquiry-oriented learning activities with a concrete visualization tool effectively enhances students' abilities to differentiate, organize, and attribute information in projectile motion problem-solving. Therefore, the Scientific Approach assisted by the Flying Water Apparatus can be considered an effective instructional strategy for fostering analytical thinking and promoting meaningful learning in physics education. Future studies should involve larger and more diverse samples from multiple schools to improve the generalizability and external validity of the findings. Additionally, researchers are encouraged to examine the effectiveness of the Scientific Approach assisted by experimental media in other physics topics and investigate its impact on additional higher-order thinking skills, such as critical thinking, problem-solving, scientific creativity, and long-term learning retention.

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