International Journal of Research in Social Science and Humanities (IJRSS)

DOI: 10.47505/IJRSS.2025.4.5

E-ISSN : 2582-6220

Vol. 6 (4) April - 2025

Development and Evaluation of Simulation-Based Guided Inquiry Learning Packet on Projectile Motion Embedded with Metacognitive Scaffolding

Meldren P. Torrevillas[1], Sotero O. Malayao Jr.[2], Giovanni J. Paylaga[3], Noel Lito B. Sayson[4], Dennis C. Arogancia[5], Ellen J. Castro[6]

[1,2,6]Mindanao State University-Iligan Institute of Technology/College of Education, Department of Science and Mathematics Education

[3,4,5]Mindanao State University-Iligan Institute of Technology/College of Science and Mathematics, Department of Physics

Philippines

ABSTRACT

Projectile motion is a foundational concept in physics, yet Grade 9 students consistently struggle with its abstractness and mathematical complexities. Traditional teaching methods often fail to address misconceptions and promote deep conceptual understanding. This study addresses this gap by developing and evaluating an edge-cutting learning packet. This study aimed to develop and assess the efficacy of a simulation-based guided inquiry learning packet embedded with metacognitive scaffolding in enhancing Grade 9 students' conceptual understanding of projectile motion. Employing the Successive Approximation Model (SAM), a learning packet was developed integrating PhET simulations, guided inquiry activities, and metacognitive prompts. The packet was validated by 16 experienced physics educators and implemented with 41 Grade 9 students in a quasi-experimental, one-group pretest-posttest design. Data was analyzed using Kendall's W, mean scores, item analysis, and normalized gain. The needs assessment revealed projectile motion as the most difficult topic, corroborated by Kendall's W (0.37), indicating moderate agreement among DepEd teachers (N=35). Expert evaluations affirmed the packet's quality with a "PASSED" rating across criteria: content, format, presentation, and accuracy. The student achievement scores significantly improved, with the mean increasing from 7.07 to 14.34. The average normalized gain was 0.56, classified as "Average." The findings advocate for a paradigm shift in physics education, emphasizing the role of metacognitive support and simulation-based inquiry to promote deeper, perturbed understanding. This research offers a replicable model for instructional design and calls for the broader adoption of innovative strategies that empower students to master challenging scientific concepts. Ergo suggests determining the metacognitive development of the students.

Keywords: Guided Inquiry, Projectile Motion, Physics Education, Simulation-based Learning, Metacognitive Scaffolding.

1. INTRODUCTION

Projectile motion is a fundamental concept of classical mechanics, underpins our understanding of phenomena ranging from the trajectory of a thrown baseball to the orbital mechanics of celestial bodies (Milan et al., 2024). This topic is particularly relevant for Grade 9 students as it forms the foundation for more advanced concepts and allows students to connect theoretical principles to everday life (Rey-Mark et al., 2022). However, despite its importance many students consistently struggle in understanding projectile motion, caused by persistent misconceptions and an inability to transfer knowledge to novel problem-solving scenarios. Specifically, students demonstrate difficulties in understanding the independent nature of horizontal and vertical motion due to the combination of constant horizontal velocity and vertical acceleration due to the gravity. The difficulty of understanding projectile motion increases because the problem-solving process needs students to use algebra and trigonometry along with the independent motion of projectiles (Chinaka, 2021; Changjan & Mueanploy, 2015). This deficiency stems from a confluence of factors, mainly from the inherent abstractness, de-contextualized and traditional teaching methods that often prioritize rote memorization over conceptual mastery (Verawati & Nisrina, 2025).

Traditional instructional methods, often characterized by lectures-based, formula driven problem-solving, and limited opportunities for active engagement, have proven inadequate in fostering deep conceptual understanding (Verawati & Nisrina, 2025). Such approaches frequently fall short to address students' pre-existing misconceptions, provide insufficient scaffolding for knowledge construction, and neglect the critical role of metacognitive processes in learning (Moser, Zumbach, & Deibl, 2017). Recognizing these shortcomings, educators have consistently and seek for innovative teaching strategies that promote active learning, inquiry-based exploration, and technology integration to increase student participation, conceptual understanding, and learning outcomes (Otero & Meltzer, 2017). Compounding this need, a needs assessment we conducted among 35 DepEd science teachers revealed that projectile motion is consistently ranked as the most difficult topic for Grade 9 students. Preliminary data from this study indicates that teachers consider students' vector decomposition struggles and their ability to grasp independent vertical and horizontal motion together with their practical applications as main barriers to learning. The gathered evidence strongly emphasizes the necessity for delivering better instructional approaches that capture student attention. This convergent evidence underscores the imperative for more effective and engaging instructional interventions.

In response to these challenges, interventions like guided inquiry based learning (IBL) have been developed, particularly through 7E's framework (Engage, Explore, Explain, Elaborate, Evaluate, Extend, Elicit) by Eisenkraft (2003) promotes active learning. Interactive computer simulations enhances guided IBL by visualizing abstract concept and dynamic processes (Arboiz & Malayao, 2024; Wen et al., 2023). However, even with the simulations, students find it challenging to choose, arrange, and incorporate pertinent material in guided inquiry-based learning activities because they are complex, and successful inquiry requires metacognition (Fan, 2015; Saadi et al., 2021). By synergistically combining these three approaches, our learning packet aims to create a transformative learning experience that promotes deeper conceptual understanding, enhanced problem-solving abilities, and greater self-efficacy in physics.

Therefore, the primary objective of this study is to develop, implement, and evaluate the effectiveness of this simulation-based guided inquiry learning packet embedded with metacognitive scaffolding in enhancing Grade 9 students' conceptual understanding of projectile motion. Specifically, this research seeks to: (1) Develop simulation-based guided inquiry learning packet embedded with metacognitive scaffolding in grade 9 projectile motion. (2) Investigate the efficacy of the developed learning packet on improving Grade 9 students' conceptual understanding of projectile motion.

2. METHODS

2.1 Research Design

The research adopts an instructional development approach designed by Dr Michael Allen of Allen Interactions in 2021 using the Successive Approximation Model (SAM). SAM is an iterative, flexible approach that allows continuous feedback-based improvement, making it suitable for refining instructional interventions. This model contains three main parts: (1) Preparation Phase composed of Information Gathering and Background; (2) Iterative Design Phase composed of Design, Prototype, and Review and (3) Iterative Development Phase composed of Develop, Implement, and Evaluate (Guden et al., 2024). The study includes a single classroom group that has undergone a simulation-based guided inquiry learning packet embedded with metacognitive scaffolding. The researcher developed, validated, and pilot test to 108 students the 20-item researcher-made achievement test to measure students' conceptual understanding, pretest was first given before the intervention of the learning packet, and posttest after 2 weeks of implementation. In this study, a one-group pretest-posttest quasi-experimental design ($O1 \times O2$) was employed during the implementation phase.

2.2 Research Subjects and Participants

DOI: 10.47505/IJRSS.2025.4.5

The participants of this study involves 41 Grade 9 students from a homogeneous section at Hinaplanon National High School, Iligan City, Lanao Del Norte, Philippines during the school year 2024-2025. The participants were selected through purposive sampling, one homogeneous section was selected to ensure controlled condition, due to its academic uniformity, meaning they share similar academic backgrounds and learning characteristics, making it a suitable group for investigating the efficacy of the learning packet. The inclusion criteria for the subjects are as follows: (a) currently enrolled in Grade 9; (b) secured the consent of their parents/guardian through consent form and (c) have no medical conditions that may affect their ability to learn.

2.3 Data Gathering Procedure

The simulation-based inquiry learning packets with embedded metacognitive scaffolding were created using the Successive Approximation Model as a guide. This entails determining the requirements of both educators and students and creating a packet that includes a lesson plan, simulation-based guided inquiry activities embedded with metacognitive prompts, and an achievement test.

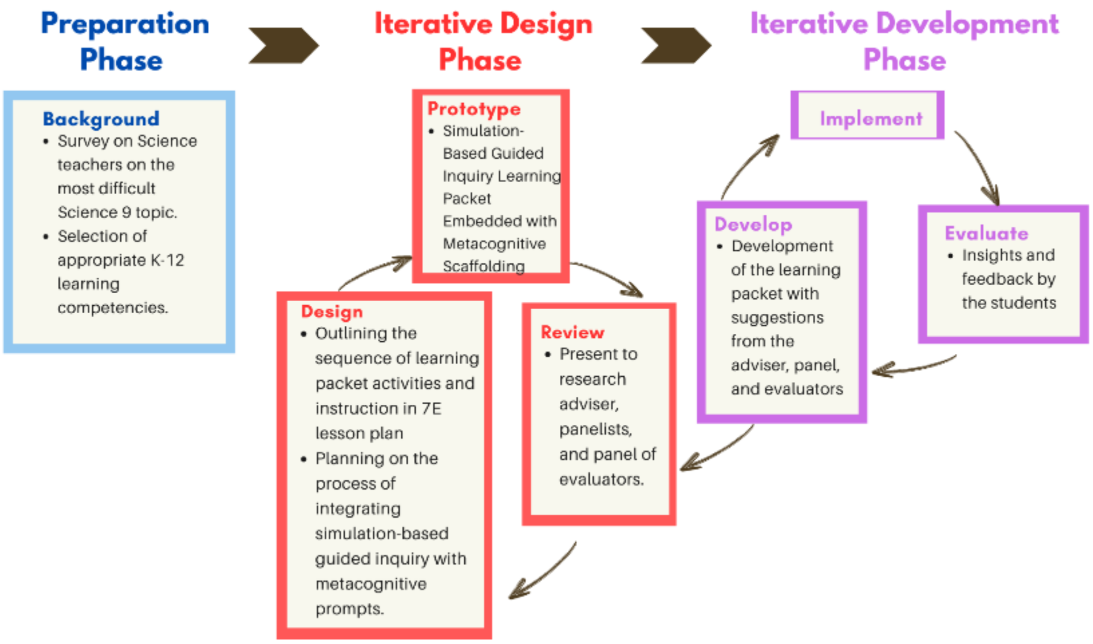

Figure 1. Step by step process of developing the learning packet using the Successive Approximation Model

To develop the simulation-based guided inquiry learning packet embedded with metacognitive prompts, the researchers adopted the Successive Approximation Model (SAM) as their instructional design framework, as illustrated in Figure 1. It involves identifying the most difficult science topic through survey which are participated by 35 DepEd science teachers. It then followed by selection of appropriate K-12 science curriculum guide learning competencies, ensuring that the instructional intervention aligns with national education standards and addresses specific learning goals for Grade 9 students.

During the Iterative Design Phase, a prototype instructional material was created based on the 7E model, incorporating simulation-based guided inquiry and metacognitive prompts. This built upon previous findings, translating learning competencies into K-12 aligned learning objectives. A detailed outline was developed to foster student engagement and critical thinking. Subsequently, detailed lesson activities were designed, and a learning packet was created to visualize the instructional process and facilitate feedback. The packet's effectiveness was evaluated and validated by 16 panel of experienced physics educator and science expert teachers.

The Iterative Development Phase focused on enhancing the learning packet through evaluations from the design phase. The suggestions implemented by advisors and a panel of evaluators were integrated into the learning packet to enhance both student experience and effectiveness while maintaining alignment with student needs and curriculum standards. The refined learning packet was then implemented with 41 Grade 9 students, whose feedback was analyzed to identify areas for further improvement.

2.4 Data Analysis

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2.4.1 Kendall's W Coefficient of Concordance

A needs assessment survey evaluated 35 DepEd science teachers by ranking which science topics needed assistance. Kendall's W was employed because it is a non-parametric statistic used to measure teacher agreement levels during the data statistical analysis phase. Teachers ranked nine science topics from most difficult to least difficult. Kendall's W scores range from 0 to 1, where 0 reveals no agreement, and 1 indicates perfect agreement among teachers (Ahudey et al., 2020). Decision-making about the intervention depends heavily on the degree of match among raters' rankings which is measured through Kendall's W. The present study incorporates Kendall's W because it is essential in evaluating agreement and decision-making processes.

2.4.2 Mean

The learning packet's evaluation was conducted using the Department of Education's Learning Resources Management and Development System (LRMDS) Evaluation Rating Sheet for Print Resources. This assessment tool evaluates four factors: (1) content, (2) format, (3) presentation/organization, and (4) accuracy and up-to-dateness of information, with each factor rated on a 4-point Likert scale (Raymundo, 2022). Descriptive statistics, specifically the mean, was employed to analyze the evaluation scores. This allowed for the determination of the learning packet's overall quality and the consistency of ratings. The learning packet's recommendation for use in public schools is contingent upon the mean score for each factor meeting or exceeding the minimum passing score. Failure to meet this criterion necessitates revisions and subsequent re-evaluation.

2.4.3 Item Analysis

An Item Analysis Matrix will categorize test items based on their difficulty and discrimination indices, guiding decisions on whether to retain, revise, or reject each item. The matrix considers difficulty levels (Difficult, Average, and Easy) and discrimination levels (Poor, Marginal, Reasonably Good, Good, Very Good) to inform item refinement (Magno & Ouano, 2010). For instance, a difficult item with poor discrimination would be rejected, whereas an average item with good discrimination would be retained.

2.4.4 Normalized Gain

To determine the efficacy of the learning packet on Grade 9 students' conceptual understanding of projectile motion, pre- and post-tests were administered. Following the tests, the normalized gain (g) was calculated to quantify the improvement in understanding. The normalized gain score was computed to gain insight into the influence of the simulation-based guided inquiry learning packet, which is embedded with metacognitive prompts, on the conceptual understanding of the Grade 9 physics students. The normalized gain value indicates the extent of increment from pretest to posttest. A positive gain corresponds to an increase, and the magnitude of the gain can be categorized as decrease, stable, low, average, or high (Coletta & Steinert, 2020).

3. RESULTS AND DISCUSSIONS

3.1 Develop simulation-based guided inquiry learning packet embedded with metacognitive scaffolding in grade 9 projectile motion.

3.1.1 Preparation Phase

Prior to designing and developing the learning packet, a needs analysis was performed. As part of this analysis, a survey was distributed to thirty-five (35) science teachers from DepEd to identify the most challenging physics topic in Grade 9. The results, summarized in Figure 2, indicated that the majority of teachers identified projectile motion as the most difficult concept to teach and the least understood by students during the fourth quarter of Science 9. The teachers' responses were analyzed using Kendall's W statistic, yielding a value of 0.37. This result suggests a statistically significant, but moderate, level of agreement among the teachers regarding the relative difficulty of various topics in the Grade 9 physics. The results of this survey align with prior studies in the field. For example, Celestino-Salcedo et al. (2024) observed similar difficulties among students in comprehending projectile motion concepts. Likewise, studies conducted by San Juan (2025), Andoy, and Rebuera (2024) have independently documented prevalent misconceptions related to projectile motion among student populations. These concurring findings across multiple studies, reinforce the understanding that students commonly face challenges and harbor misconceptions regarding projectile motion.

DOI: 10.47505/IJRSS.2025.4.5

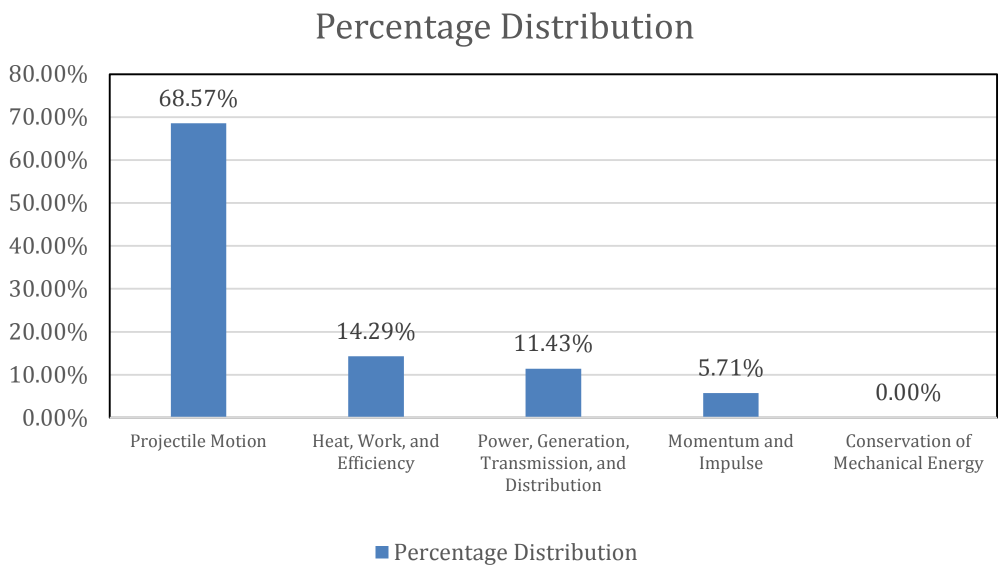

Figure 2. Distribution of Teacher-Ranked Difficulty Levels for Grade 9 Physics Topics (N = 35)

3.1.2 Iterative Design Phase

The learning packet's content was developed in accordance with the content standards outlined in the Department of Education's K-12 curriculum guide. The researcher utilized a learning packet evaluation tool, adapted from the Department of Education's LRMDS Evaluation Rating Sheet for Print Resources, to assess four key factors: (1) content, (2) format, (3) presentation/organization, and (4) accuracy and up-to-dateness of information. Following the development of a 7E lesson plan, the integration of PhET simulations, guided inquiry activities, and metacognitive prompts, including illustrations/photos was all created using the free version of Canva—was implemented. Six activities were included: an introduction to projectile motion, exploration of horizontal and vertical motion, uniformly accelerated motion (UAM), projectile launched horizontally, projectile launched at an angle, and a problem-solving activity. Additionally, three sets of metacognitive prompts, designed as reflections and summary, were incorporated. These activities were designed for a two-week implementation period. The learning packet underwent four iterative revisions, driven by feedback and suggestions from evaluators, to maximize its effectiveness in facilitating student learning. These revisions specifically targeted the refinement of instructional content, improvement of activity alignment with learning objectives, enhancement of metacognitive prompts, and optimization of the structure of guided inquiry activities. Table 1 presents the summary of the comments and suggestion on the learning packet, where 'E' in the 'Codes' column refers to the Evaluator's comment number. The feedback gathered from the evaluators were categorized and summarize to streamline the revision process.

Table 1. Categorized Comments and Suggestions on Learning Packet

Version 1		
Category	**Code**	**Comments and Suggestion**
Formatting and Visual Presentation	E1, E3, E6, E10, E16, E15	Improve figure quality and arrangement; ensure consistent font usage and appealing color scheme; provide adequate answer spaces.
Content Accuracy and Clarity	E2, E4, E5, E7, E9, E15	Ensure correct terminology and equations; clarify concepts like gravity direction; differentiate distance and displacement; provide clear equation derivations, object specifications, and variable legends; enhance equation text quality.
Pedagogical Approach and Question Design	E12, E13, E14, E15, E16	Enhance question design to encourage observation and critical thinking; avoid simple yes/no questions; start with experiments before theory; increase problem-solving exercises.

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Enhancements and Additions	E8, E11, E15, E16	Highlight references; include more challenging equations and additional practice problems to enrich content.
Version 2		
Category	**Code**	**Comments and Suggestion**
Terminology and Presentation	E2, E4	Replace terms like "shoot" with "launch"; improve equation quality by writing them manually; ensure sample situations fit learner experience.
Visual and Design Enhancements	E5, E6, E7	Overall content and design are good; Improve PhET picture arrangement; redesign image solutions for clarity; use PT Serif or Lora font style.
Accuracy and Consistency	E8, E9, E10, E11, E15	Check gravity unit; use 'h' for height; correct equation 3 (horizontal); showcase unit cancellations; ensure examples match challenge problems.
Version 3		
Category	**Code**	**Comments and Suggestion**
Copyright and Context	E3, E4	Check Angry Birds animation usage allowance; contextualize the cover page without overly highlighting Angry Birds.
Accuracy and Consistency	E8, E9, E10, E15, E16	Reiterate feedback on gravity unit, height variable, horizontal equation correction, example consistency, and figures in problems.
Presentation and Clarity	E12, E13	Box final answers; clarify Challenge Yourself instructions; add answer key after the page; remove colon in references.

In Version 1, the focus was more on foundational elements. The suggestions addressed formatting issues (E1, E3, E6, E10, E15, E16), which are crucial for ensuring a both visually appealling and learning packet accessibility. Content accuracy and clarity (E2, E4, E5, E7, E9, E15) were prioritized to prevent misunderstandings and correctness of information. Furthermore, the comments for a more effective pedagogical approach and question design (E12, E13, E14, E15, E16) to stimulate critical thinking among students. Finally, the feedback encouraged strategic more enhancements and additions to incoprate (E8, E11, E15, E16) to enrich the learning experience. In Version 2 saw adjustments that refined the learning packet's terminology and presentation (E2, E4), as confusing terms were clarified for better understanding. Addressing the visual and design elements (E5, E6, E7) ensured a better learning environment. Emphasis was placed on accuracy and consistency (E8, E9, E10, E11, E15), ensuring the technical content was correct and the examples consistently aligned with the learners. Lastly, Version 3 concentrated on addressing copyright issues (E3, E4) related to the Angry Birds photos, and further refining accuracy and consistency (E8, E9, E10, E15, E16). The changes improving presentation and clarity (E12, E13) helped improve the understandability, which led to the overall quality of the learning packet.

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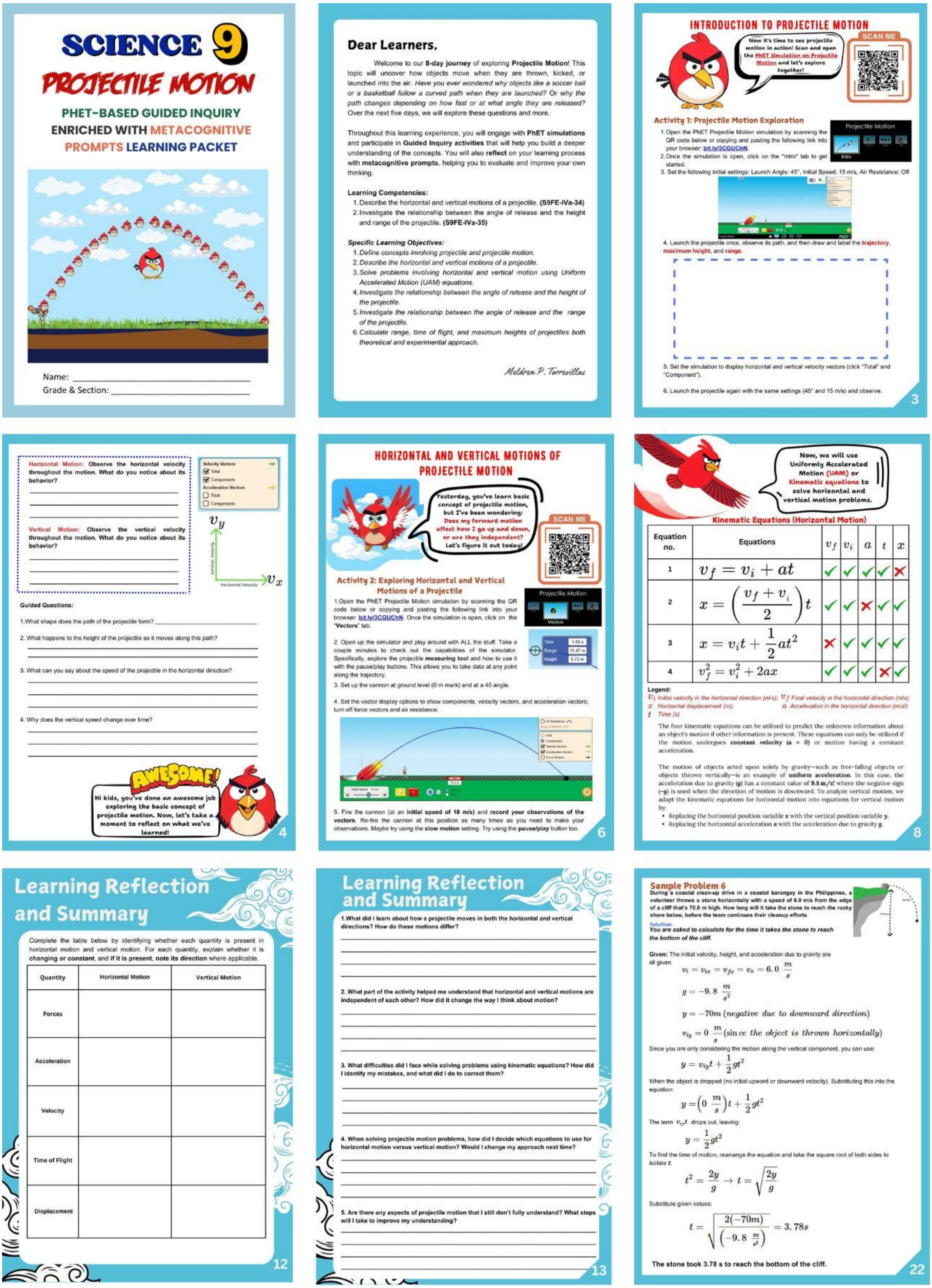

Figure 3. Sample page from Developed Learning Packet on Projectile Motion

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3.1.3 Iterative Development Phase

The simulation-based guided inquiry learning packet embedded with metacognitive scaffolding was evaluated by sixteen (16) teachers, and their ratings across four factors are consolidated below. Table 2 summarizes their ratings across four key factors with each factor meeting the required minimum score for a "PASSED" decision.

Table 2. Evaluation of the In-Service Teachers on the Learning Packet (N=16)

Factor	Criteria	Mean Rating	Decision
Factor 1: Content	Content is suitable to the student's level of development	3.81	Minimum score of 21/28
	Content is suitable to the student's level of development	3.75	
	Development of higher cognitive skills	3.81	
	Material is free of biases	4	
	Material enhances desirable values and traits	3.44	
	Potential to arouse reader interest	3.69	
	Adequate warning/cautionary notes	3.63	
	Total Points	**26.13**	**PASSED**
Factor 2: Format	Size of letters is appropriate	3.75	Minimum score of 54/72
	Spaces between letters and words facilitate reading	3.75	
	Font is easy to read	3.88	
	Printing is of good quality (i.e., no broken letters, even density, correct alignment, properly placed screen registration).	3.69	
	Simple and easily recognizable	3.82	
	Clarify and supplement the text	3.81	
	Properly labelled or captioned	3.81	
	Realistic/appropriate colors	3.88	
	Attractive and appealing	3.69	
	Culturally relevant.	3.81	
	Attractive and pleasing to look at	3.81	
	Simple (non-distracting)	3.69	
	Adequate illustration in relation to text	3.63	
	Harmonious blending of elements	3.75	
	Paper used contributes to easy reading.	3.75	
	Durable binding to withstand frequent use.	3.81	
	Easy to handle.	3.81	
	Relatively light.	3.88	
	Total Points	**68.02**	**PASSED**
Factor 3: Presentation and Organization	Presentation is engaging, interesting, and understandable.	3.88	Minimum score of
	There is logical and smooth flow of ideas.	3.88	
	Vocabulary level is adapted to target reader's likely experience and level of understanding.	3.63	
	Length of sentences is suited to the comprehension level	3.69	

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	of the target reader.		15/20
	Sentences and paragraph structures are varied and interesting to the target reader.	3.69	
	Total Points	**18.77**	**PASSED**
Factor4: Accuracy and Up-to-datedness of Information	Conceptual errors.	4	Minimum score of 24/24
	Factual errors.	4	
	Grammatical errors.	4	
	Computational errors.	4	
	Obsolete information.	4	
	Typographical and other minor errors (e.g., inappropriate or unclear illustrations, missing labels, wrong captions, etc.).	4	
	Total Points	**24**	**PASSED**

The evaluation of the simulation-based guided inquiry learning packet by sixteen (16) in-service teachers showed that it met all required benchmarks, receiving a "PASSED" decision across four key factors. The highest rating (4.00) was in accuracy, confirming the material's reliability and error-free content, while the lowest **(**3.44**)** was in enhancing values and traits, indicating a potential area for improvement. The format and presentation were well-received, with minor suggestions for refining vocabulary and improving the adequacy of illustrations. The results validate the learning packet as an effective instructional tool, with opportunities for enhancement in visual elements and character-building components to further enrich student learning.

3.2 Investigate the efficacy of the developed learning packet on improving Grade 9 students' conceptual understanding of projectile motion.

The researcher initially created 30 conceptual questions. This set of questions was then pilot-tested with a group of Grade 10 students at Suarez National High School. The item analysis of a 30-question projectile motion test, pilot-tested on grade 10 student, resulted in 27 items (90%) being retained, 1 item (3.33%) needing revision, and 2 items (6.67%) being rejected as shown in Table 3. This suggests that while most questions effectively assessed student understanding, a significant portion required improvement or removal due to issues like difficulty or clarity. Following the pilot test, the final achievement test, used as both a pretest and posttest, comprised a total of 20 questions selected from the original pool since the test was designed to be completed within a 45-minute period, only 20 items were selected from the 27 retained questions. The selection was based on several criteria: ensuring balanced coverage of learning objectives, prioritizing items with strong discrimination indices, and considering time efficiency to prevent cognitive overload. This approach ensured that the final test was valid, reliable, and practical**,** effectively measuring students' understanding of projectile motion while allowing them to complete the assessment within the allotted time.

Table 3. Summary of Item Analysis for the Test Questionnaire in Projectile Motion

Final Evaluation/ Remark	Frequency	Percent	Test Item Number
Items to be "**RETAINED**"	27	90%	1,2,3,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21, 22,23,24,25,26,27,28,29
Items to be "**REVISED**"	1	3.33%	4
Items to be "**REJECTED**"	2	6.67%	15, 30
Total	**30**	**100%**	**30**

Assent and consent forms were distributed three weeks prior to the study's implementation. The study included 41 student participants. Pretest and posttest results were analyzed to determine individual gain scores, revealing a notable difference in scores following the use of the learning packet. The intervention spanned two weeks. The data from

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Table 4 indicates a notable improvement in student achievement test scores from pretest to posttest. Specifically, the average score nearly doubled, increasing from 7.07 to 14.34. This substantial rise suggests that students, on average, demonstrated a better understanding of the projectile motion after the instructional intervention. The average gain score of 0.56, categorized as "Average," provides a nuanced perspective. While the overall improvement is significant, the "Average" gain suggests that the learning packet led to moderate learning gains. This metric helps to temper expectations, indicating that while progress was made, there is still room for optimization. Additionally, Figure 4 indicates the individual performance of the students, results shows that most students achieved 'average' individual gain scores, suggesting that the learning packet had a positive, yet moderate, impact on their learning performance.

Table 4. Summary of the Average Normalized Gain

Achievement Test	Mean Average	Average Gain Score	Interpretation
Pretest	7.07	0.56	Average
Posttest	14.34		

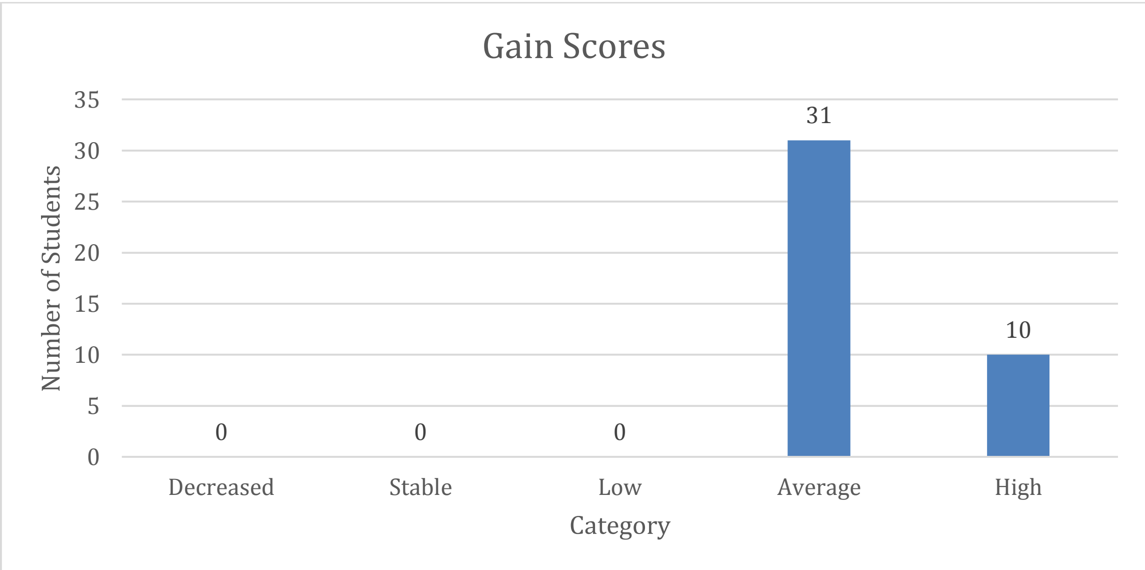

Figure 4. Gain Scores of Students

4. CONCLUSION AND RECOMMENDATION

The study successfully developed and evaluated a simulation-based guided inquiry learning packet embedded with metacognitive scaffolding for Grade 9 projectile motion. Teacher evaluations indicated that the packet was "PASSED" across content, format, organization and presentation, and information accuracy. Furthermore, implementing the learning packet resulted in a statistically significant improvement in students' conceptual understanding of projectile motion. Achievement test results showed students achieved better understanding after post-test scoring at 14.34 than the pretest score of 7.07, which translated to an average gain score of 0.56, classified as Average normalized gain. These findings suggest that the learning packet proves helpful for teaching projectile motion to students according to test results, yet its effectiveness may still be improved. Further research should investigate long-term effects, impact on diverse students, and the student's metacognitive development.

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