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Comic-Polya Method Integration in Physics: Enhance Students' Conceptual Understanding and Motivation

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ABSTRACT

Purpose of the study: Filipino students' declining science performance calls for innovative instructional methods. This study evaluated the effects of integrating comic-based instruction and the Polya Method in Grade 8 Physics lessons at Opol National Secondary Technical during the 2023–2024 school year.

Methodology: Thirty-six students were selected using convenience sampling. Employing a mixed-method approach, this study used a one-group pre-test and post-test design and focus-group discussions for qualitative data. Conceptual understanding and science motivation were assessed over one month using a 30-item pre- and post-test aligned with the Department of Education competencies.

Main Findings: Pre-test results from 86.11% of students who needed improvement categories were high. After the intervention this percentage distribution decreased to 13.89%, with improvements in the categories of satisfactory (30.56%) and outstanding (13.89%). Qualitative analysis indicated increased science motivation (moderately high to high), and thematic analysis revealed enhanced engagement, enjoyment, academic performance, and problem-solving skills. Post-intervention, mean test scores rose from 11.31 to 19.69 ($t = 13.786$, $P = 0.0001$), demonstrating the effectiveness of combining comic-based learning with Polya's method.

Novelty/Originality of this study: This research presents newly gained perspectives on incorporating comic-based learning and the Polya Method to enhance the conceptual understanding and science motivation of Filipino secondary students in selected Physics lessons. Thematic analysis unveiled three unique themes that contribute to the science education research literature focused on the Philippines and these strategies.

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1. INTRODUCTION

Physics is often considered one of the Philippines' most challenging high school subjects. The poor academic performance of students in this discipline is frequently linked to their difficulties in understanding the content and their lack of adequate mathematical and problem-solving skills [1]-[3]. Physics requires the application of mathematical concepts to investigate and solve problems, and its abstract nature makes comprehension difficult, necessitating greater motivation for learning [4], [5]. These insights align with Kaptan and Timurlenk [6] that low self-confidence and motivation are common issues in science education [7]-[9].

Moreover, Tolentino and Roleda [10] found that students have difficulty achieving low physics achievement, particularly in concepts like force, work, energy, and power. However, the Philippines faces challenges in physics education, with Filipino students' achievements falling below international standards [10], [11]. Similarly, studies have shown Grades 6, 10, and 12 pupils and students have shown a steady decline in science subjects in the National Achievement Test (NAT) assessments falling to "low mastery" or "low proficiency," below the Department of Education's (DepEd) standard of 75% [12], [13]. At the local level, it was found that the four divisions of the Department of Education, Cagayan de Oro City, Gingoog City, El Salvador City, and Misamis Oriental, demonstrated that the NAT performance in the school year 2017-2018 for primary and secondary students with four subjects (Filipino and History) obtained high scores, while Mathematics and Science had low scores [14].

The same results were found at Opol National Secondary Technical School, a public high school in Misamis Oriental. The secondary students, particularly Grade 10, with low science scores, performed poorly on the National Achievement Tests. Also, the classroom observations by researchers indicated that Grade 8 test items mirrored the students' difficulties in problem-solving and understanding scientific concepts. This deficiency in problem-solving skills in physics led to lower summative assessment scores for the least developed competencies, especially in Grade 8 Science, during the first quarter of 2022-2023, specifically in physics lessons. Academic achievement and the performance of learners in science have been a matter of great concern to school managers and teachers in the education sector [15]. The decline in public high school students' scientific literacy necessitates improving Science education in the Philippines since teaching quality greatly affects learner performance [16]. Moreover, according to educators in physics, conceptual understanding and motivation are critical factors that contribute to student's success in science, as demonstrated by previous research [17]-[19].

Conceptual understanding refers to students' understanding of fundamental concepts and principles [20], [21]. This enables them to draw logical conclusions and innovatively transform knowledge into diverse forms, such as insightful ideas. Solving physics problems is impossible without conceptual understanding, and applying them involves using techniques and steps to solve them [22]. Conceptual understanding helps students learn physics problems, allowing them to search for related concepts to study and develop their critical thinking skills [23]. While learners' motivation is crucial in learning, it also determines why people engage in a given action or pursue a specific goal [24]. Studies also indicate that motivation and self-efficacy significantly influence the development of students' conceptual processes in physics [25]. Nevertheless, for the current students enrolled in the 2023-2024 school year in Grade 8 Science at Opol National Secondary Technical School, their conceptual understanding of physics and motivation to learn physics concerning their problem-solving skills, particularly in Newton's Laws, Potential, and Kinetic Energy lessons, remain unexplored and needs further research in this grade year level.

Also, earlier researchers in the Philippine setting used comic-based learning as instructional material to improve the poor performance of learners in science subjects, such as physics and biology, in public high schools. Comics are a visual form of information transmission that combines images and text in a narrative storyline to facilitate science learning [26]-[28]. A study in a Cavite public school with a grade 8 student from Luzon used a comic-based learning module in selected topic lessons in physics over four weeks. Results showed significant improvement in students' understanding of physics concepts and motivation [29].

According to a study conducted by Pinili [30] at Pagsanjan National High School with Grade 7 students, using a comic-themed booklet led to a notable improvement in their understanding of physics concepts, as indicated by increased test scores. Similar findings were found in Grade 10 students at Tucdao National High School in Kawayan, Biliran, and Visayas, who also used the comic method in biology. The contextualized comic book in context brought about a significant improvement in understanding cell division in their pre-test and post-test scores [31]. Likewise, Grade 11 students in the Accountancy, Business, and Management Strand at Graceville National High School in Bulacan, Luzon, found that a developed comic effectively taught photosynthesis concepts in biology [32]. Although various authors in the Philippines have researched comic-based learning in the Luzon and Visayas regions, the Polya Method has not been integrated. Also, no data is available in Mindanao, which is one of the missing gaps, particularly in the public junior high school population. The Polya method has been proven to improve student performance over traditional methods [33], [34].

Selçuk & Çalýskan [35] state that the problem-solving framework "comprises four stages: understanding the problem, devising a plan, executing the plan, and reviewing the process." Likewise, problem-solving abilities are regarded as the most important skills of the 21st century [36]. The Department of Education (DepEd) identifies problem-solving skills, critical thinking, and information literacy as essential in K-12 education. Teachers were recommended to include these skills in their teachings, according to Mahinay et al. [37]. This study addresses the research gap by providing baseline data and insights from a public high school in Mindanao, Philippines, an underrepresented area in previous studies. This study introduces the incorporation of the Comic-Polya method in physics education in the Mindanao region, where such innovative strategies have not been ventured before. Given Filipino students' persistently low performance in physics, there is an urgent need

to adopt novel instructional strategies that can enhance conceptual understanding and motivation. The Comic Pólya method, with its proven effectiveness in previous findings, offers a promising solution to these educational challenges. Immediate implementation of these findings could significantly improve physics education outcomes, align with national academic standards, and address students' critical need for improved scientific literacy and problem-solving skills.

The findings can inform the development of context-specific interventions and support the Department of Education's goal of integrating critical thinking and problem-solving skills into the K-12 curriculum. The success of the comic-based learning module and the Polya Method can guide curriculum developers and policymakers in creating engaging and effective educational materials for physics and other science subjects.

The poor performance of Filipino students in physics, especially in grasping the core concepts and applying problem-solving skills, is an excellent challenge in education. Though some studies are related to implementing comic-based learning and the Polya method, respectively, as a combined approach for the Philippine setting is very scarce. The present study aims to fill this gap by examining how comic-based instruction, combined with the Polya method, affects conceptual understanding and motivation at the Grade 8 level. This study may enable the stakeholders to discover an approach that can rectify the immediate educational needs of those above. This study was conducted to determine the effect of using a comic-based learning module and Polya Method integration on students' conceptual understanding of the selected topics in physics, science motivation questionnaires, and problem-solving skills among Grade 8 students in their science subjects in the first quarter of the school year 2023-2024 at Opol National Secondary Technical. Specifically, the research had three primary objectives:

1. Determine the students' pre-test and post-test scores of conceptual understanding in Newton's Laws, Potential, and Kinetic Energy lessons and science motivation before and after comic-based learning and the Polya Method integration.
2. Identify themes emerging from students' experiences with comic-based learning and the Polya Method through focus group discussions.
3. Examine whether a significant difference exists between students' pre-test and post-test scores in conceptual understanding and science motivation for Grade 8 Science using comic-based learning and the Polya Method integration.

2. RESEARCH METHOD

2.1. Research Design

This study employed a mixed-method approach, combining quantitative and qualitative data. The main reason for using a mixed-method research (MMR) strategy is to expand the study's scope, allowing for both breadth and depth of investigation. For instance, a researcher can generalize findings to a population while gaining a detailed understanding of a phenomenon's significance to individuals. Collecting closed-ended and open-ended qualitative data enhances comprehension of the research problem [38]. Additionally, qualitative methods like interviews and focus groups provide deeper insights through narratives [39].

Furthermore, the pre-test and post-test collected quantitative data to evaluate changes in students' conceptual understanding and motivation to learn comic-based learning in Physics and the Polya Method integration. Semi-structured interviews in Cebuano local dialects and translated into English were conducted in a focused group discussion (FGD) to collect qualitative data to supplement the quantitative data, adapted and modified from the study [29]. A one-group pretest-posttest quasi-experimental design was also used because it is more feasible and costs less than a true experimental design [40].

2.2. Population and Research Sample

The study population focused on Grade 8 students enrolled at Opol National Secondary Technical School for the 2023-2024 academic year. This institution is situated in Taboc, Opol Misamis Oriental, within the Northern Mindanao region of the Philippines. As noted by Naelga and Mila [41], the school is located in the eastern part of the municipality of Misamis Oriental. The researchers employed a convenient sampling technique to determine the study participants. Convenience Sampling is low-cost and easy, and the subjects are readily available for a group of participants [42], [43]. Thirty-six (36) participated in this research study for four weeks, from September to October 2023, the first quarter of the lessons.

2.3. Data Collection Technique

Before the researchers collected data, a formal consent letter was sent to the school principal's office. The letter asked permission to conduct the study and discussed the research goals and objectives. Then, in compliance with DepEd order no—16 series, 2017, and the Data Privacy Act of 2012 for ethical standards, consent forms were distributed to participants' parents before data gathering began. Researchers started gathering the data once the consent forms had been collected from participants. The study started with an initial pretest before the comics-based learning intervention, with the 30-item multiple-choice test for the students.

The text focused on the student's conceptual understanding of physics as adapted from previous studies [44]-[49]. The questionnaire was aligned using the Department of Education's Grade-8 Science curriculum guide. Participants were requested to complete the science motivation questionnaire (SMQ-II) used by Glynn et al. [50]. The next stage of the study focuses on four weeks of teaching Physics to Grade 8 students using comics-based learning modules. Students had 30 minutes before each class to read the modules incorporating the Polya Method Strategy [29], [51].

The final stage involved a post-test identical to the pretest. Furthermore, a focus group discussion (FGD) semi-structured interview with local dialects in Cebuano was also translated into English. The 36 students were divided into six groups of six members each. The researchers then asked them how they liked comic-based learning and the Polya method integration, their experience, and why. The interviews lasted 30 minutes.

2.4. Data Analysis

Combining different data analysis methods can offer more insights and support using descriptive and inferential methods. The descriptive statistical method emphasizes the percentage distribution, mean, and standard deviation. The mean represents the arithmetic average, and the standard deviation shows response variability [52], [53]. The inferential analysis involved a paired-sample t-test at a 0.05 significance level to evaluate differences between pre-test and post-test scores. Cohen's measure of the effect size indicates the difference between pre-test and post-test mean scores [53]. We adopted the qualitative interpretation data analysis on science motivation from Galarosa and Tan [54] and Benben and Bug-os [55]. A thematic approach analyzed the data collected for focus group discussions, explicitly identifying the different themes from the various responses of students [56], [57].

2.5. Research Procedure

Ethical Approval and Consent: Ethical Clearance was obtained from the school heads, and Informed Consent was obtained from the parents/guardians of participants. Pre-test Administration: A 30-item pretest, supported by the SMQ-II for measuring science motivation, was administered to measure conceptual understanding. Intervention: This study applied a four-week intervention to teaching physics topics using comic-based learning integrated with the Polya method. Post-test Administration: The same pre-test items and SMQ-II were administered as the post-test. Focus Group Discussions: Qualitative data on the students' experiences were collected through Focus Group Discussions.

3. RESULTS AND DISCUSSION

3.1. Results

Figure 1 shows the percentage distribution of the respondents' pre-test scores before the intervention in conceptual understanding of Newton's Laws, Potential, and Kinetic Energy Lessons. 86.11% (31 out of 36) of participants scored 14 or below, revealing widespread difficulty with conceptual understanding in the lesson, with most scoring below the passing mark.

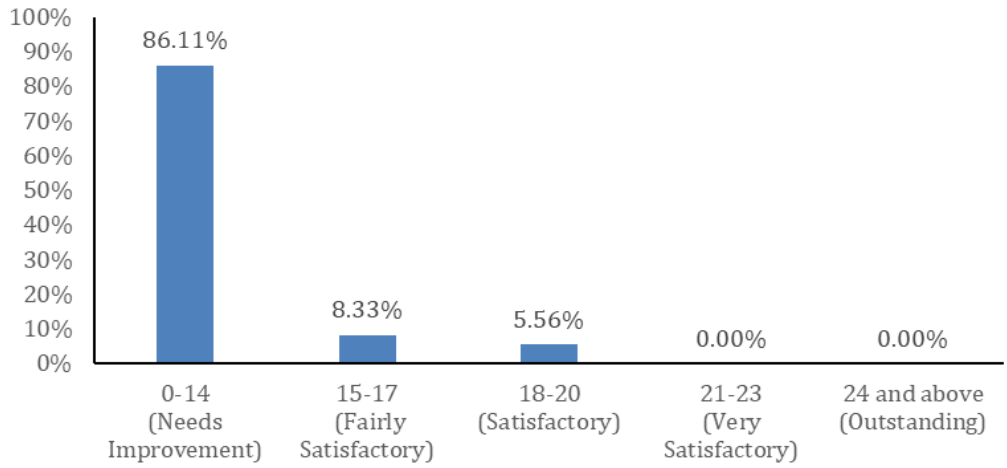

Figure 1. Percentage distribution of respondents' pretest scores on conceptual understanding

Figure 2 shows the percentage distribution of post-test scores after integrating comic-based learning and the Polya Method. In the pre-test, 86.11% of the students required improvement, which decreased to 13.89% after the intervention. Furthermore, the percentage distribution increased significantly, with 30.56% allocated to the satisfactory and very satisfactory categories and 13.89% to the outstanding category. Before the intervention,

the percentage distribution was 5.56% for satisfactory and 0% for satisfactory and outstanding categories. This indicates a significant improvement in conceptual understanding compared to pre-test scores.

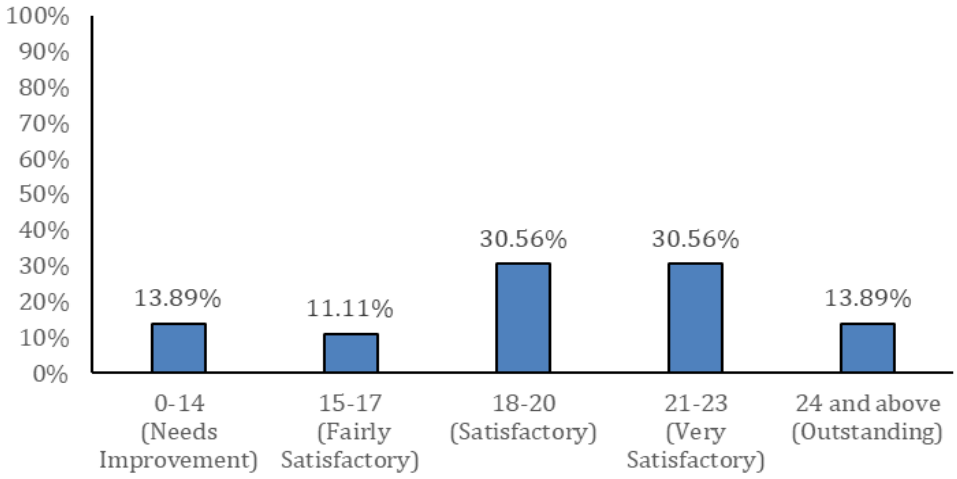

Figure 2. Percentage distribution of respondents' post-test scores on conceptual understanding

Table 1 shows the results of the participants' science motivation questionnaire with the five components before and after comic-based learning, and the Polya Method integration was applied to Grade 8 students. Before the intervention, the average scores for science motivation (i.e., intrinsic motivation, self-efficacy, and self-determination) were 2.76, 2.77, and 2.67, respectively, comparable to grade motivation, indicating a moderately high level, while the career motivation scored 2.5. After the intervention with comic-based instruction, there was a significant increase in science motivation among grade 8 students. Mean scores for intrinsic motivation and self-efficacy increased to 3.76, self-determination to 3.65, grade motivation to 3.79, and career motivation to 3.7.

Table 1. Science Motivation in Pre and Post-Comic-Based Learning and Polya Integration

Motivation Categories	Pre-Comic and Polya Integration		Post-Comic and Polya Integration	
	Mean	Qualitative Interpretation	Mean	Qualitative Interpretation
Intrinsic Motivation	2.76	MH	3.76	H
Self-Efficacy	2.77	MH	3.76	H
Self-Determination	2.67	MH	3.65	H
Grade Motivation	2.67	MH	3.79	H
Career Motivation	2.5	L	3.7	H

Legend:

Range	Qualitative Description	Qualitative Interpretation
5.00-4.21	Usually	Very High (VH)
4.20-3.41	Sometimes	High (H)
3.40-2.61	Rarely	Moderately High (MH)
2.60-1.81	Never	Low (L)
1.80-1.00	Always	Very Low (VL)

Table 2 shows the interview responses from the focus group discussions on students' experiences with comic-based learning and the Polya Method integration. Three themes emerged from the thematic analysis: enhanced engagement and enjoyment, improved academic performance, and increased motivation and problem-solving skills. Thus, the findings add new knowledge to the science education literature in the Philippines, where previous researchers did not report these findings.

Table 2. Focus group discussions with students' responses on comic-based learning and the Polya Method

Themes	Student Responses
Enhanced Engagement and Enjoyment	Before, our teacher never utilized comics in the classroom. I lacked the desire to learn because the modules or books were overly full of text and thus dull. However, everything altered when our teacher began employing comics; the study became enjoyable as the latter employed images to represent concepts and encouraged me to read through them. Physics is simple to comprehend via comic books because they employ words and illustrations to transmit concepts, thus providing me with a cause to study.
Improved Academic Performance	Before the teachers used comics, the scores on our quizzes were not very high. However, many students in our class did better after we used comics. Comics are beneficial as they assist in comprehending a difficult Physics lecture. Thanks to the visual representation of topics in the comics, I understood the lesson, and my grades improved.
Increased Motivation and Problem-Solving Skills	Physics lessons can be very challenging as they involve much problem-solving. However, using comics tends to motivate us to study and integrate the Polya Method, which is essential for properly developing our problem-solving skills in learning physics. This method helps us understand the problem and plan how to solve it.

Table 3 reveals a significant improvement in Grade 8 students' conceptual grasp of physics through comic-based learning and the Polya Method. The pretest average was 11.31 (SD = 3.11), rising markedly to 19.69 (SD = 3.8) post-intervention. The average score difference was 8.38, indicating a significant improvement in students' understanding. The t-value of 13.786 and p-value of 0.0001 confirm the statistical significance of these results, suggesting the change was not by chance.

Additionally, Cohen's D, exceeding 1.00, underscores the substantial effect of the intervention, emphasizing its effectiveness in enhancing Grade 8 students' physics comprehension.

Table 3. Difference in Students' Pretest and Posttest Scores of Conceptual Understanding for Grade 8 Science

Variables	Mean	SD	Mean Difference	t-value	p-value	Cohen's D
Pretest	11.31	3.11				
			8.38	13.786	0.0001	>1.00
Posttest	19.69	3.8				

With a 0.05 level of significance

3.2. Discussion

The results in Figure 1 align with pre-test scores, which were also below the minimum criteria before Sari's comic-based learning intervention [58]. A similar trend was observed in another study, which indicated that students' physics learning was generally low before the introduction of comic-based educational materials [59]. The distribution percentages for fairly satisfactory, satisfactory, very satisfactory, and outstanding were 8.33% and 5.56%, respectively, and notably lower for the latter two, with no respondents in these categories. This observation suggests intervention strategies are necessary to enhance conceptual understanding and performance in Newton's Laws and Potential and Kinetic Energy lessons in Grade 8 students. In Figure 2, after the intervention, there is a significant improvement in conceptual understanding compared to pre-test scores. These findings align with previous research by Utami et al. [60] and Damayanti and Kuswanto [61], who reported increased post-test scores with comic-based learning materials. The elevated post-test scores suggest that students potentially gained a more profound comprehension of and enthusiasm for the subject matter by relating scientific principles to familiar characters and narratives. This approach may have facilitated better retention of scientific lessons and improved academic performance [62]. Comparable results were observed in research conducted by Tilley et al. [63], demonstrating that employing comic strips as instructional tools in science classes could enhance scientific literacy and boost student performance in specific concept areas. Their study revealed that students who interacted with comic strips exhibited superior understanding and retention of scientific concepts compared to traditional text-based resources. The pre-test and post-test outcomes confirmed a significant increase in mean scores among students utilizing comics, indicating that the narrative structure and visual elements effectively supported the learning process.

In Table 1, the science motivation questionnaire reflects a low level, consistent with Badeo and Koc [29], who noted that students of this age have not considered their career paths yet. Consequently, students did

not perceive acquiring scientific knowledge as leading to a professional future. These findings align with previous studies on students' science motivation, with intrinsic motivation (M = 2.76), self-efficacy (M = 2.77), and grade motivation deemed moderately high [54]. However, career motivation (M = 2.5) was lower, suggesting the need for interventions to boost future career aspirations in science. After the intervention of comic-based learning, students' science motivation increased. Lin et al. [64] support that comics can enhance student interest and intrinsic motivation in science, as corroborated by Piaw [65], who found that comics boost learning motivation. Farinella [66] and Badeo and Koc [29] further suggest that engaging plots and relatable comic characters enhance self-efficacy. Students were found to have higher mean scores in self-determination because they believed they put much effort into studying physics [24].

The thematic analysis of the focused group discussion in Table 2 revealed three key themes: enhanced engagement and enjoyment, better academic outcomes, and increased motivation and problem-solving skills. These findings contribute novel insights to science education in the Philippines, as previous studies had not reported such results. However, similar findings by Lin et al. [64] assert that comic media enhances students' interest and enjoyment in learning. Linardatos and Apostolou [67] observed that digital comic creation's perceived enjoyment, usefulness, and ease significantly affect students' preferences. Kim et al. [68] reported that students using educational anatomy comics achieve better learning outcomes than those without. Cholisoh [69] found that comic media boosts student interest and learning outcomes regarding global warming symptoms. Comic-based learning also improves motivation and problem-solving skills. Annisa et al. [70] demonstrated that the comic-based Andro-Web module aids Grade 11 students in developing problem-solving skills in physics, particularly ideal gas topics. Moreover, using comics as teaching materials increases students' interest, motivation, and understanding of physics learning.

Furthermore, Table 3 shows the difference in students' pretest and post-test conceptual understanding scores for Grade 8 Science. This notable increase mirrors the findings by Badeo and Koc [29] who observed a similar rise in post-test scores of 29.21 following comic-based learning. Haroky et al. [71] corroborated these results, highlighting the positive impact of comic media on learning outcomes. The average score difference was 8.38, indicating a significant improvement in students' understanding.

Results of this study show that comic-based learning and the Polya method can be effectively integrated to improve learning outcomes in physics among Grade 8 students. Its positive effects on both conceptual understanding and science motivation indicate that this study may provide an effective and meaningful intervention toward enhancing science education in the Philippines. This, in turn, can influence curricular programs and teacher education in the constant endeavor towards attaining higher scientific literacy among Filipino youth. Unique insights from thematic analysis, which have not been reported in similar Philippine studies, further enrich the knowledge of practical pedagogical approaches.

The study's limitations highlight significant concerns that need attention. One notable limitation is using a one-group pretest-posttest design without a control group [72]. Future research should utilize true experimental designs with random assignments to better assess the strategy's effectiveness, reduce bias, and enhance validity and reliability.

4. CONCLUSION

The study evaluated the effects of integrating comic-based instruction and the Polya Method in Grade 8 Physics selected topic lessons in the first quarter. The findings indicated that the comic-based learning module and the integration of the Polya Method were effective teaching strategies for selected Physics topics lessons for Grade 8 students. Before the intervention, 86.11% of participants scored below the passing mark, as evidenced by their pre-test scores. However, the post-test results noted remarkable improvement, with only 13.89% needing improvement and a significant increase in students attaining satisfactory and outstanding scores. More students achieved both satisfactory and outstanding scores. The mean score increased significantly from 11.31 to 19.69, with a difference of 8.38, a corresponding t-value of 13.786, and a p-value of 0.0001. As measured by Cohen's D, the effect size exceeded 1.00, confirming the intervention's effectiveness. Moreover, the qualitative data analysis of science motivation showed a significant shift from moderately high to high after the intervention, indicating a positive effect. The thematic analysis of the three themes revealed that the intervention improved engagement, enjoyment, academic performance, motivation, and problem-solving skills. Thus, these findings of the thematic analysis, which the previous researchers in the Philippines did not observe, provide additional knowledge to the scientific literature on the effectiveness of these two strategies, comic-based learning, and the Polya Method, in science education at the secondary level in the Philippines. This makes it a promising teaching strategy for physics science education in public high schools to improve performance in science.

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