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Enhancing Secondary School Learners' Problem-Solving Skills in Physics Using the 5E Learning Model: A Convergent Parallel Mixed-Method Study

Jennivie L. Sagario
Graduate School, Nueva Vizcaya State University & Saint Teresita's Academy, Philippines, *jhenasagario10@gmail.com*

Reymund C. Derilo
Corresponding author, Graduate School, Nueva Vizcaya State University, Philippines, *rcderilo@nvsu.edu.ph*

Divine Grace A. Mones
Graduate School, Nueva Vizcaya State University & Saint Catherine's School, Philippines, *monesdivinegrace@gmail.com*

Rolly C. Quizon Jr.
Graduate School, Nueva Vizcaya State University, Philippines, *arjayquizon29@gmail.com*

Through a convergent parallel mixed-method design, qualitative and quantitative data were collected and analyzed to evaluate the effectiveness of 5E method in this study. Qualitative data were collected from open-ended responses of all student participants (n=40) and from a follow-up FGD with 17 selected students. These responses were subjected to thematic analysis, which revealed a range of challenges encountered by learners. Quantitative data, on the other hand, were gathered from the students' performance in the Physics achievement. Qualitative analysis uncovered a range of challenges faced by students, including those related to students' abilities, instructional strategies, subject matter complexity, and external factors. Quantitative findings from a one-group pretest-posttest quasi-experimental study revealed significant improvements in students' problem-solving abilities post-intervention, supported by the Wilcoxon Signed-Ranks Test results. The integration of qualitative and quantitative data, along with meta-inferences, highlights the efficacy of the 5E learning model in addressing these challenges. Pre-intervention convergence of data outlines barriers contributing to students' low proficiency in physics problem-solving, while post-intervention convergence outcomes demonstrate notable enhancements in problem-solving skills and learning engagement.

Keywords: 5E-learning model, physics education, problem-solving skills, mixed methods meta-inferences, learning

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INTRODUCTION

Based on observations, young Filipino learners often encounter significant difficulties when solving problem sets in Physics, struggling with identifying given information, determining required outcomes, selecting appropriate formulas, and performing unit conversions. These challenges are further reflected in the Philippines' low ranking in the Programme for International Student Assessment (PISA), where it placed 79th out of 81 participating countries in 2018 (OECD, 2019) and dropped further to 80th out of 81 countries in 2022 (OECD, 2023). Although PISA assesses general scientific literacy rather than subject-specific proficiency, its results offer valuable insight into students' foundational science understanding. The Philippines ranks in 2018 and 2022 PISA reflect persistent difficulties in applying scientific knowledge, interpreting data, and reasoning through evidence—skills central to physics learning. While PISA does not isolate physics performance, these trends suggest systemic issues that likely affect students' abilities in physics. This study addresses such challenges by implementing the 5E learning model in a physics context, examining its potential to overcome cognitive and motivational barriers reflected in large-scale assessments. Moreover, the observed disinterest and negative attitudes of learners towards physics problem-solving worsen this situation. Thus, this study aims to delve into the factors behind students' disinterest in Physics problem-solving and to identify the specific challenges they face in this domain.

Research examining problem-solving in physics education, particularly investigations into the behaviors of both 'experts' and 'novices' (Ince, 2018), offers valuable insights into the strategies employed by students during problem-solving tasks, as well as the processes through which problem-solving skills are developed within classroom and laboratory settings.

Problem-solving skills involve the ability to identify issues, explore and select from various possible solutions, and make decisions that effectively resolve the problems. These skills require the integration of knowledge and practical abilities to address situations appropriately. Equipping all students with problem-solving skills is essential, as these abilities are crucial for addressing future challenges and contributing to the development of their societies (Ewies et al., 2021). Problem-solving skills can also be developed through instructional strategies that place students in simulated or real-life scenarios, allowing them to practice and strengthen their problem-solving abilities (Cumilang et al., 2025; Sainapha at al., 2024). Creating an optimal learning environment is a shared responsibility that requires emphasizing the importance of interactions both within and beyond the classroom (Derilo, 2024). Expert problem solvers demonstrate consistent and efficient utilization of problem-solving strategies, typically beginning by contextualizing problems within the framework of physics laws and formulas before employing mathematical methods for resolution. Their approach typically involves a systematic progression of steps, including problem comprehension, concept identification, strategy formulation, problem-solving execution, and outcome evaluation. Conversely, novice problem solvers often initiate problem-solving tasks by focusing on mathematical expressions without initially grasping underlying conceptual frameworks. Success in solving physics problems hinges not solely on conceptual comprehension but also on adeptly establishing connections between different parts of the problem. Experts invest more time in comprehending problem details and concept relationships, particularly in intricate scenarios, whereas novices often encounter challenges in synthesizing these connections, particularly in complex problem-solving contexts.

Several literatures highlight strategies to enhance students' problem-solving skills. Lomagdong (2023) emphasizes identifying students' learning-style preferences for tailored instruction, while Intaros and Inprasitha (2023) stress anticipating students' ideas through various lesson components. Metpattarahiran (2023) demonstrates the flipped classroom's effectiveness in promoting critical thinking, and Nemiño (2023) underscores teaching for independent learning's impact on academic performance and self-esteem. These findings collectively emphasize tailored instruction, idea anticipation, technology integration, and independent learning's role in developing problem-solving skills among learners.

In the contemporary educational milieu, fostering adept problem-solving skills is of paramount importance, especially within secondary school physics education, as it lays the groundwork for students' future career pathways. One innovative instructional approach that has shown promise in enhancing these skills is the 5E learning model (Cakir, 2017; Feyzioğlu & Ergin, 2012; Gu, 2023; Ma'arif et al., 2020; Rosdianto & Teeka, 2020; Sumadi & Inna, 2019; Yonwilad et al., 2022). This approach encompasses five distinct phases: engage, explore, explain, elaborate, and evaluate, each of which actively involves students in the learning process, thereby promoting deeper understanding and retention of concepts. The 5E learning model has been found to positively impact problem-solving skills in various educational contexts. Ma'arif et al. (2020) and Rosdianto and Teeka (2020) both reported significant improvements in students' problem-solving abilities when using the 5E model. This was further supported by Gu (2023), who highlighted the model's potential in Chinese elementary education. Yonwilad et al. (2022) also demonstrated the effectiveness of the virtual 5E instructional organization in enhancing mathematical problem-solving abilities. Khamsong (2022) also supports the 5E learning model explaining that it enhances students' understanding of a topic in science classes. The study explains that the phases of engaging, exploring, explaining, elaborating, and evaluating help students construct knowledge, proving beneficial in various scientific fields where students struggle with adapting and absorbing information. In summary, these studies highlight the value of the 5E approach in promoting problem-solving skills across different subjects and educational levels.

Numerous studies have explored effective methods for enhancing problem-solving skills. Smith et al. (2019) conducted a meta-analysis revealing that active learning strategies, such as collaborative problem-solving and case-based learning, significantly improve students' problem-solving abilities. Research also highlights the importance of cognitive strategies in developing these skills. García-Martínez et al. (2021) emphasized the role of creativity in boosting problem-solving capabilities. Together, these studies show that active learning, cognitive training, and creativity are essential for developing problem-solving skills.

However, despite advancements in secondary school physics education, several research gaps persist. Specifically, there is limited knowledge about the effectiveness of the 5E learning model in physics, which needs further exploration. While several international studies address students' problem-solving skills, there are few studies conducted in the Philippines. The country needs research to address the gaps faced by Filipino learners nationwide. To address these issues, the current study employs a convergent parallel mixed-methods design, combining qualitative and quantitative data for a comprehensive approach. Additionally, this study focuses on a specific population gap by examining underrepresented students in a public rural high school, a demographic often overlooked in educational research. While prior studies have demonstrated the effectiveness of the 5E learning model in general science and mathematics education, limited research has examined its impact specifically on physics problem-solving among Filipino learners. This study addresses that gap by applying the 5E model within a rural public high school setting—a context largely underrepresented in existing literature. Moreover, by integrating a convergent parallel mixed-methods design, the study offers a comprehensive analysis that captures both cognitive challenges and motivational factors influencing students' problem-solving skills.

This study aimed to evaluate the effectiveness of the 5E learning model in improving students' problem-solving skills in Physics. Specifically, it sought to identify the challenges students face when solving Physics problems, assess their skill levels before and after the model's implementation, analyze any significant differences in performance, and examine the convergence or divergence between qualitative and quantitative data related to their problem-solving abilities.

METHOD

Research Design and Methods

This study used a convergent mixed methods design (Creswell & Plano Clark, 2018). The convergent design aims to obtain different but complementary data on the same topic (Morse, 1991) to thoroughly understand the research problem. This design combines the strengths of quantitative methods (large sample sizes, objective measures, generalization) with those of qualitative methods (small sample sizes, subjective interpretation, detail) (Patton, 2014). It is used to compare quantitative results with qualitative findings, corroborate and validate data, illustrate results, and examine relationships among variables by incorporating insights from both data types (Creswell & Plano Clark, 2018). Figure 1 shows the MMR framework of this study.

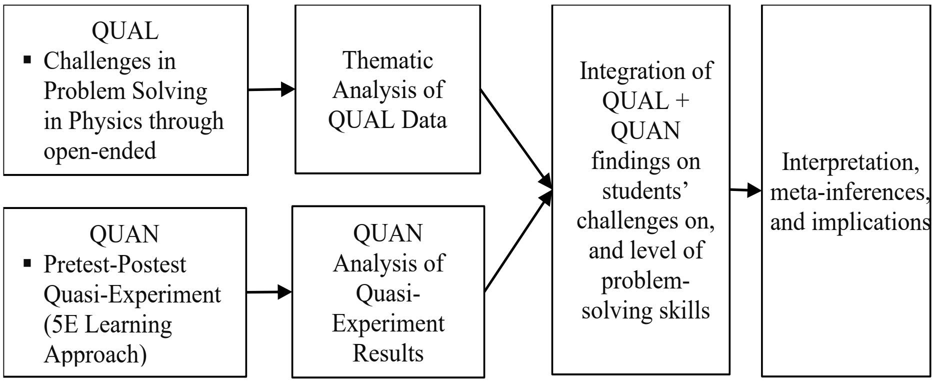

Figure 1
The research framework employing Creswell and Plano Clark's (2018) Convergent Mixed Methods Approach

The primary objective is to examine the challenges experienced by secondary school students in solving physics problems, specifically those involving one-dimensional motion, and to evaluate the effectiveness of the 5E learning model in improving their problem-solving skills. The study incorporates both qualitative and quantitative components to provide a comprehensive understanding of the phenomenon under investigation. Qualitative data were collected through open-ended questions (n=40) and small group discussions from selected 17 participants to identify the challenges students faced in solving physics problems. These data were thematically analyzed using Braun and Clarke's (2022) reflexive analysis. Quantitative data were obtained using a one-group pre-test-posttest quasi-experiment method (n=40), comparing students' problem-solving performance before and after the intervention. The results from both methods were then analyzed side by side to identify points of convergence. Using both quantitative and qualitative methods allowed the converging data to produce triangulated results, providing a thorough understanding of the topic (Khunou & Rakhudu, 2022).

Research Locale and Sampling Technique

The study employs a purposive sample of grade seven learners from a rural public secondary school in southern Nueva Vizcaya, Philippines. This specific locale was chosen to allow researchers to observe and analyze educational practices and outcomes in a setting that, while smaller, can reflect broader trends seen in larger schools. By examining the dynamics within this rural educational context, the researchers aim to gather insights that can inform educational practices and policies on a wider scale.

The sampling technique involves selecting students who meet specific criteria to ensure the validity of the study's findings. The primary criterion for selection is that the students have no prior exposure to the 5E learning model. This ensures that any observed changes in their problem-solving skills can be attributed to the intervention itself, rather than to previous experiences with similar teaching methods. This approach allows the researchers to accurately assess the impact of the 5E learning model on the students' abilities to solve physics problems involving one-dimensional motion. The second criterion is that the students must belong to a heterogeneous class. This means the class includes students with varying levels of ability, backgrounds, and learning styles. Selecting students from a heterogeneous class is important because it mirrors the diversity found in typical classroom settings. This diversity allows the researchers to assess the effectiveness of the 5E learning model across a range of student abilities and learning needs, ensuring the results are more generalizable and applicable to a broader student population. It also helps in understanding how different students interact with and benefit from the intervention, providing a more comprehensive evaluation of its impact.

By focusing on a rural public secondary school, the study also highlights educational challenges and opportunities unique to rural settings. This can provide valuable data that may be used to tailor educational strategies to better suit the needs of students in similar environments, thereby enhancing the overall effectiveness of educational interventions across diverse contexts.

Instruments

Open-ended Questionnaire. The open-ended questionnaire has six questions about the challenges students encounter in solving Physics problems, difficult topics, and their perceptions of Physics. The instrument was reviewed by higher education professors and tested on a sample not part of the study to ensure clarity and answerability.

Semi-structured Interview Protocol for Students. The semi-structured interview protocol was employed during focus group discussions (FGD) prior to the intervention to validate and delve deeper into the challenges highlighted in the open-ended questionnaire. It consisted of 10 questions covering different facets of challenges in Physics learning, such as complex or confusing subject areas, difficult topics or scenarios, and reasons behind struggles with Physics. Likewise, a post-intervention interview guide was prepared to determine the parts of the lesson students like most and least. Before implementation, the instrument underwent evaluation for clarity and relevance by three higher education professors. Written comments and suggestions for refining clarity and alignment with research objectives were incorporated prior to use in focus group discussions.

Physics Test. The tool composed of 40-item multiple-choice problem sets focusing on identification of problem-solving skills of students in one-dimensional motion. The items were validated by science experts with at least five years of experience, were used to measure student problem-solving ability. The problem sets underwent pilot testing to confirm their validity, and their reliability was assessed using the Kuder-Richardson Formula 20 (KR-20), resulting in a high reliability coefficient of 0.90.

Lesson Design Using the 5E Learning Model. The intervention was built around a meticulously designed lesson plan anchored on the 5E Learning Model, which emphasizes a student-centered approach to learning through five key phases: Engage, Explore, Explain, Elaborate, and Evaluate. This model fosters deeper understanding and retention by guiding students through a structured yet flexible learning progression. Table 1 shows a summary of the different phases of the 5E learning model.

Table 1
The description of the different phases of the 5E learning model

Phase	Description
Engage	In the Engage phase, students are introduced to the lesson through an activity or question that captures their interest and stimulates prior knowledge, setting the stage for learning.
Explore	During the Explore phase, they actively investigate the concept through hands-on activities, experiments, or collaborative tasks that encourage discovery and critical thinking.
Explain	In the Explain phase, students articulate their understanding through discussions and presentations, as they connect their findings to key scientific principles and clarify their ideas
Elaborate	The Elaborate phase challenges students to apply their newfound knowledge in novel or real-world contexts, further deepening their comprehension and extending their learning.
Evaluate	Finally, in the Evaluate phase, students demonstrate their understanding and skills through assessments, reflections, or other feedback mechanisms, enabling both the teacher and the students to gauge learning progress effectively.

To ensure the lesson plan's effectiveness and alignment with curricular goals, it was thoroughly developed and rigorously validated by a panel of experts. This panel included three experienced secondary school science teachers and a subject area coordinator for science, ensuring the content's relevance, accuracy, and pedagogical soundness. The 5E lesson plan served as the foundation of the intervention, promoting active learning and critical thinking among students while addressing the targeted learning objectives. Table 2 shows the summary of quantitative rating of the evaluator across 3 main criteria: content quality, instructional quality and technical quality.

Table 2
Summary of quantitative ratings of the evaluators on the 5E model lesson plan

Criteria	M	SD	Quality Interpretation
Content Quality	3.65	0.42	Very Good
Instructional Quality	3.85	0.22	Very Good
Technical Quality	3.54	0.49	Very Good

Note: 1-1.49: Very Poor; 1.50-2.49: Poor; 2.50-3.49: Good; 3.50-4.00: Very Good

Data Analysis

Thematic Analysis. The qualitative data collected from various sources, including the open-ended questionnaire, interviews with respondents underwent thematic analysis following the Braun and Clarke (2022) reflexive TA. This involved systematically coding and organizing raw qualitative data into meaningful groups or themes. Throughout the process, peer and expert validation, as well as frequent monitoring, were observed to ensure rigor and reliability. Thematic analysis served multiple purposes, including data reduction, organization, pattern identification, and interpretation. It enabled the researchers to identify factors contributing to challenges in students' problem-solving difficulties.

Statistical Analysis. The study used mean and standard deviation to assess students' problem-solving skills in Physics, which provided insights into their average performance and the variability of their scores. To ensure the appropriateness and validity of the statistical techniques employed, all necessary assumptions were thoroughly examined and confirmed to have been met. A Shapiro-Wilks' test indicated that the distribution of Pretest ($W(40) = 0.963$, $p > 0.05$), and Posttest ($W(40) = 0.978$, $p > 0.05$) scores did not differ significantly from a normal distribution. To determine whether there was a significant improvement after the intervention, a dependent samples t-test was conducted to compare pretest and posttest scores. This inferential analysis, set at a 95% confidence level, helped establish the effectiveness of the intervention in enhancing students' problem-solving abilities.

Joint Display Integration. Qualitative data from focus group discussions (FGD) and the open-ended questionnaire were analyzed alongside quantitative data from the quasi-experimentation. This approach facilitated a holistic understanding of the effects of integrating the 5E learning model in solving Physics problems. By integrating qualitative and quantitative data, researchers were able to triangulate findings and gain a deeper understanding of the challenges, strengths and capabilities of the learners in solving physics problems

Ethical Considerations

In the pursuit of ethical conduct, the study sought approval from the administrators of the secondary school setting through a formal letter, outlining the intention to conduct the research within the school premises. This step ensured transparency and respect for the institution's policies and regulations. Furthermore, to uphold ethical standards, informed consent forms were prepared and distributed to the parents of the students involved in the study. The purpose of these forms was to provide detailed information about the research, its objectives, potential risks and benefits, and the rights of the participants. Those students whose consent forms were not signed were excluded from the study. By obtaining consent from these parties, the researchers ensured that all stakeholders were fully informed and voluntarily agreed to participate in the study. Moreover, the researchers made sure to safeguard the confidentiality of all participant data. This included protecting sensitive information obtained during interviews, focus group discussions, and any other data collection methods used. Confidentiality measures were implemented to ensure that participant identities and responses remained anonymous and were only accessible to authorized personnel involved in the research process.

FINDINGS

Challenges in Solving Problems in Physics

The analysis of students' responses to the open-ended questions and their contributions during the subsequent focus group discussions were systematically organized thematically, as depicted in Figure 2. Four primary domains of challenges emerged from this analysis: student-focused challenges, subject matter-focused challenges, instruction-related challenges, and external factors. Each domain encompasses various aspects that contribute to students' difficulties in learning Physics.

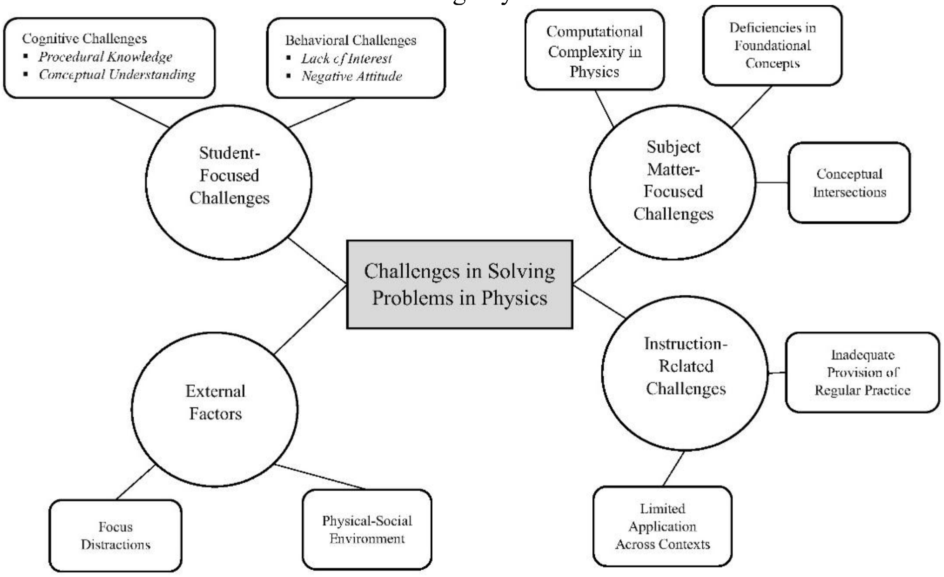

Figure 2
Dimensions and subdimensions of students' challenges in solving problems in physics

Student-focused Dimension. This dimension encompassed cognitive and behavioral aspects, highlighting difficulties in procedural knowledge, conceptual understanding, lack of interest, and negative attitudes towards Physics. Some of the challenges met are because of the way students think and behave. For example, they might find it hard to understand the steps needed to solve a problem, or they might struggle to grasp the main ideas in solving problems in Physics. Others might just not be interested in Physics or feel like they cannot do well, which can make it hard for them to keep trying when they encounter problems. This is evident in the following responses:

> It's hard for me to solve problems because there are a lot of numbers to solve. I'm not very familiar with the solving steps because it's confusing…also because I find it difficult to solve and follow the solving steps and formulas (Participant 3, p.1).
>
> Even though I listen, I still don't get it. I also struggle because problem-solving is the most difficult and the least liked by me. I'm also weak in Math, so I find it difficult. (Participant 27, p.4)
>
> I don't like physics because I didn't listen to my teacher and I was so lazy to review my notes (Participant 11, p.11); Because I struggle with Physics, I'm not interested in it (Participant 19, p.4).

Subject Matter-focused Dimension. This dimension revealed issues related to the calculation-heavy nature of Physics, gaps in foundational concepts, and conceptual overlaps contributing to confusion among students. Physics problems involve lots of mathematical computation, which can be tough for students. Sometimes, students have not learned the basic ideas they need to understand more complicated Physics problems. And sometimes, different Physics concepts overlap, which can make things even more confusing for students. These challenges were observed from the responses of Participant 3, 26 and 33:

> Sometimes, I don't find it difficult. But sometimes, I struggle because I don't fully understand... It's hard for me to solve Physics problems in Science because there are difficult numbers to solve, like in Mathematics (Participant 3, p.3).
>
> I find solving Physics problems difficult because Math itself is challenging for me. So, combining Math with Science makes it even more challenging. However, I always try my best for the sake of my grades (Participant 26, p.4).
>
> Because initially, the concept was not introduced to us when we learned the other formulas. so i find it hard to cope up with the lesson because the first concepts were not taught (Participant 33, p.3).

Instruction-related Dimension. This dimension pointed out shortcomings in applying theoretical knowledge to practical contexts and the lack of regular practice opportunities, hindering students' ability to master Physics concepts. Students might not see how what they learn in class applies to real-life situations. And if they do not get enough practice solving problems regularly, they might not feel confident when they are faced with a new problem. In fact, participant 8 mentioned:

> I don't see the use of Physics in real life and with my other subjects. I also struggle with solving Physics problems because sometimes I don't understand. The examples provided to us are also insufficient for me to memorize the steps of solving (Participant 8, p.11).

External Factors. This dimension highlighted distractions and environmental influences that affect students' learning experiences, including classroom conditions, noise levels, and external pressures. Outside factors like distractions or the environment can also make problem-solving harder for students. Noise or other things happening around them can make it tough to concentrate. And if they do not have the right resources or a good space to work in, that can also make it harder for them to focus and do well. The following student participants opined:

> Sometimes I don't understand since my classmate talks to me, it's like my mind wanders away from the lesson (Respondent 15, p.3).
>
> I find it difficult to solve Physics problems because sometimes I don't understand. It's also because of the noise from people inside and outside the classroom (Respondent 17, p.4).

Students' Proficiency in Solving Physics Problems

The students' proficiency in problem solving were determined before and after the utilization of the 5E learning model. Tables 3 and 4 shows the results of the analysis.

Table 3
Students' Proficiency in Solving Physics Problem Prior to Implementation of the 5E learning model

Scores Range	Frequency (n=40)	Percentage	Level
30-40	2	5.00	Very High
20-29	15	37.50	High
10-19	17	42.50	Low
0-9	6	15.00	Very Low

The results shown in Table 3 reveal that the majority of students exhibited a low level of proficiency in physics problem-solving prior to the implementation of the 5E learning model. Specifically, 42.50% of the participants fell within the low proficiency range, scoring between 10-19. This indicates that a significant portion of the students struggled with effectively solving physics problems related to one-dimensional motion. Additionally, 15% of the participants demonstrated very low proficiency, scoring between 0-9, further highlighting the challenges faced by a notable subset of students.

Conversely, a smaller but notable proportion of students showcased relatively higher levels of proficiency, where 37.50% of students achieved a high level of proficiency, scoring between 20-29. This indicates a considerable competency in problem-solving skills among this group.

Table 4 presents the students' level of skill in solving physics problems after implementing the 5E learning model. The significant findings reveal an improvement in proficiency levels compared to the pre-intervention stage. The data indicate a substantial shift towards higher proficiency levels, with 85.00% of participants achieving a very high level of proficiency, scoring between 30-40. This suggests that most students demonstrated significant improvement in their problem-solving skills after engaging with the 5E learning model. Additionally, 12.50% of participants attained a high level of proficiency, scoring between 20-29, further corroborating the overall positive impact of the intervention.

Table 4
Students' proficiency in solving physics problems after implementing the 5E learning model

Range	Frequency (n=40)	Percentage	Level
30-40	34	85.00	Very High
20-29	5	12.50	High
10-19	1	2.50	Low
0-9	0		Very Low

Interestingly, only 2.50% of participants remained in the low proficiency range, scoring between 10-19, indicating a notable decrease in the number of students struggling with problem-solving skills compared to the pre-intervention stage. These results highlight the effectiveness of the 5E learning model in addressing and mitigating challenges previously faced by students.

Table 5
Comparison of students' proficiency in physics problem-solving before and after implementing the 5E learning model

	Mean	SD	t	df	p	Remarks
Pre-test	17.35	7.062	-11.003	39	<.001	Significant
Post-test	32.88	4.983				

Results shown in Table 5 indicate a substantial improvement in students' proficiency in physics problem-solving after implementing the 5E learning model. Prior to the intervention, the pre-test mean score (M=17.35, SD=7.062) reflects a relatively low level of proficiency. However, following the intervention, the mean score on the post-test (M=32.88, SD=4.983) indicates a notable improvement in the students' problem-solving skills. Statistical analysis revealed a significant difference between the pre-test and post-test scores at t (39) = -11.003, p<.001, which suggests that the improvement observed is not due to chance but rather attributed to the effectiveness of the 5E learning model. These findings underscore the positive effect of innovative teaching approach in improving students' problem-solving abilities in physics.

DISCUSSION

Challenges in Solving Problems in Physics

The thematic analysis of students' responses revealed four interrelated dimensions that contribute to the challenges they face in solving problems in Physics: student-focused, subject matter-focused, instruction-related, and external factors. Among these, the student-focused dimension was the most prominent which highlights cognitive and behavioral barriers such as poor procedural knowledge, limited conceptual understanding, and negative attitudes toward Physics. Many students reported struggling with identifying steps in problem-solving and expressed low self-efficacy, particularly due to their weak mathematical skills. This echoes findings from previous research indicating that students' mindset and self-perception play a crucial role in academic performance, especially in technical subjects like Physics.

Subject matter-related difficulties further compounded these challenges, particularly the math-intensive nature of Physics and the lack of mastery of prerequisite concepts. Students reported being overwhelmed by complex calculations and confused by overlapping concepts, especially when foundational ideas were not introduced sequentially. These issues suggest that content delivery in Physics may benefit from more scaffolded instruction, which would allow students to build a solid conceptual base before tackling multi-step problems. The instruction-related dimension supports this, revealing that students often do not see the real-world relevance of Physics or receive adequate practice, which undermines their ability to transfer theoretical knowledge to practical contexts.

External factors, on the other hand, such as classroom distractions and poor learning environments were found to negatively impact focus and comprehension. Students noted that noise, peer interruptions, and lack of resources made it harder to engage with lessons and sustain attention during problem-solving activities. These findings underscore the importance of addressing not only instructional design but also the learning environment to support meaningful engagement with Physics. These dimensions of challenges faced by students highlight the complex interplay of cognitive, pedagogical, and environmental factors in students' problem-solving performance. Addressing these issues holistically through learner-centered approaches, real-world applications, and consistent practice may help mitigate the barriers identified and improve students' proficiency and attitudes toward Physics.

Students' Proficiency in Solving Physics Problems with the 5E Learning Model

The results presented in the previous section provide insights into the effectiveness of the 5E learning model in improving students' proficiency in physics problem-solving. Prior to implementing this approach, most students struggled with problem-solving in physics, particularly in one-dimensional motion. However, after incorporating the 5E approach, there was a noticeable improvement in their problem-solving abilities.

A considerable proportion of students demonstrated low proficiency levels before the implementation of the 5E learning model, with a significant percentage falling within the low and very low proficiency ranges. According to Reddy and Panacharoensawad (2017) the high failure rate in physics is due to their inability to understand the basic subject matter content, principles of physics in formulas. It leads to lack of remembering problem-based equations in physics. To overcome these obstacles, it is recommended that each student be given the ample time and opportunity to solve the physics problems during the process of learning physics. This result is supported by the study of Ince (2018) wherein it has been pointed out that students' physics problem-solving abilities have affected the levels of metacognition, achievement, attitudes, motivation, self-efficacy and self-confidence. Hence, there is really a need for teachers to find a way to improve participants' problem-solving skills.

Conversely, following the implementation of the 5E approach, majority of students exhibited a very high level of proficiency in problem-solving. This indicates a substantial enhancement in their skills. Furthermore, the comparison between pre-test and post-test scores revealed a significant difference, with a notable increase in mean scores after the intervention. These findings underscore the effectiveness of the 5E learning model in improving students' problem-solving skills in physics. Hence, the study suggests that the 5E learning model can be a valuable tool in enhancing students' understanding and proficiency in solving physics problems. It provides educators with a useful method to improve learning outcomes in STEM education.

The findings of this study align with previous research by Siwawetkul (2018) and Ardi (2021), which emphasized the positive impact of the 5E learning model on student achievement. Additionally, the results of this study are consistent with the findings of Smith and Johnson (2019) and Jones et al. (2020), who demonstrated the significant effectiveness of the 5E learning model in enhancing students' problem-solving abilities in physics, particularly in tasks related to one-dimensional motion. Furthermore, Kozcu Çakır and Güven (2019) found the greatest effect of the 5E model in physics courses, supported by Oteles (2020), who observed increased student motivation. Yonyubon et al. (2022) affirmed the positive impact of 5E learning management plans on science learning.

The systematic integration of each stage of the 5E learning model in the study played an essential role in promoting active engagement, inquiry, conceptual understanding, application, and assessment, ultimately leading to enhanced problem-solving skills and positive learning outcomes, as evidenced in the results of the quasi-experimentation. The 5E learning model, comprising five key stages (Engage, Explore, Explain, Elaborate, and Evaluate), proved instrumental in facilitating effective learning and contributing to favorable outcomes. In the Engage phase, the teacher aims to capture students' interest and stimulate curiosity through real-life examples and engaging activities (Bybee, 2014; Gabel, 1999). This initial phase set a positive tone for subsequent exploration and fostered interest in problem-solving, aligning with the study's findings. During the Explore phase, students actively participated in hands-on activities to deepen their understanding (Bybee, 2014; Lawson, 1995). This phase, observed through the teacher-participant's provision of real-world problems, encouraged critical thinking and application of knowledge, thereby enhancing problem-solving skills among students. In the Explain phase, the teacher provides clear explanations to address misconceptions and reinforce key concepts (Bybee, 2014; Trowbridge & Bybee, 1996). This scaffolding, demonstrated by the teacher-participant in the study, likely supported the development of students' solid knowledge base, essential for effective problem-solving. In the Elaborate stage, students extend their learning through application in new contexts (Bybee, 2014; Lawson, 1995). This phase promoted higher-order thinking and transfer of learning, potentially contributing to positive outcomes in problem-solving among student-participants. This aligns with the global shift in education, where educators increasingly emphasize the development of 21st-century skills—prioritizing the application and transfer of knowledge over rote memorization—with research showing that prior mathematical knowledge significantly enhances problem-solving competence (Djudin, 2023).

Lastly, in the Evaluate phase, students' understanding was assessed through various forms of assessment (Bybee, 2014; Trowbridge & Bybee, 1996). The evaluation component of the prepared lesson for this study likely provided valuable feedback to both student- and teacher-participants, which reinforced learning and driving further improvement in the students' problem-solving skills.

Overall, the structured and sequential nature of the 5E learning model used in the study, coupled with its emphasis on active participation and application, aligns closely with the positive outcomes observed in the study.

Integration of qualitative and quantitative findings

Integrating quantitative and qualitative data enhances the effectiveness of mixed methods research (Creswell & Plano Clark, 2018; Skamagki et al., 2024; Younas et al. 2023). By integrating results, qualitative data can validate quantitative findings, while quantitative data can help in creating the qualitative sample or explaining qualitative results. Additionally, qualitative insights can inform the development or refinement of quantitative tools or interventions and generate hypotheses for quantitative testing (O'Cathain et al., 2010).

In this study, integration using joint display was used, which is shown in Table 6. When using joint displays, researchers integrate data by visually combining quantitative and qualitative findings to extract new insights that are not apparent from separate analyses. This integration can be achieved through organizing related data in formats such as tables (Fetters et al. 2013; Fetters & Guetterman, 2021).

Table 6
Integration, meta-inference and interpretation of qualitative and quantitative findings on students' challenges and performance in physics problem-solving

Quantitative Results	Qualitative Findings	Meta-inference and Interpretation
Pre-test Mean Score: 17.35 Description: Low Level	The FGD results show that students encounter difficulty in solving physics problems due to: ▪ Cognitive barriers: procedural knowledge and conceptual understanding ▪ Behavioral barriers: low interests and negative attitude ▪ Instruction-related barriers: inadequate provision of regular practice, limited application across contexts ▪ Subject matter-emanating barriers: complexity and confusion, calculation challenges, problem solving difficulties, understanding issues, differentiation, frequent practice, conversion, language barrier, general struggles, ▪ External factors such as distractions and environment and	*There is a convergence of qualitative and quantitative findings:* The alignment between the low mean score and the detailed qualitative barriers suggests that improving students' proficiency in physics problem-solving requires addressing these multifaceted challenges. An integrated approach (such as the 5E learning model) can help in developing interventions that address both cognitive and non-cognitive barriers, thereby improving students' problem-solving skills and overall performance in physics.
Post-test Mean Score: 32.88 Description: Very High	Post-intervention interview results show that: ▪ Students appreciate problems that involve simple and straightforward calculations, which highlight the importance of clear and manageable tasks in maintaining student interest and confidence in problem-solving. "*The part of the lesson I liked most was solving distance because it's enjoyable to solve...you just multiply it and you get the answer*" (Participant 17, p.10). ▪ A significant number of students enjoyed the lessons that included diverse and engaging activities. This reflects the effectiveness of the 5E learning model's emphasis on hands-on, interactive learning experiences, which can enhance student engagement and motivation. "*What I liked most about the lessons was the introduction of various activities*" (Participant 5, p.9).	*There is a convergence of qualitative and quantitative findings:* The convergence of the post-test mean score (qualitatively described as very high) and the post-intervention interview results indicates a positive impact of the teaching intervention (5E model) on students' problem-solving skills and attitudes towards learning in physics.

The convergence of both quantitative and qualitative data brings light on the various challenges hindering students' proficiency in physics problem-solving. The low mean score of the students in the pretest indicates a struggle among students which reflects a deficiency in fundamental understanding and application. The qualitative insights from the focus group discussion (FGD) and open-ended question responses underscore various barriers contributing to this problem. These barriers range from difficulties in comprehending concepts and procedures to a pervasive disinterest or negative attitude towards physics. Insufficient practice worsen the problem, compounded by the failure of instruction to connect theoretical concepts with real-world relevance. The inherent complexity of physics problems, coupled with mathematical challenges and external distractions, further impedes students' progress. Addressing these challenges necessitates a comprehensive approach. It involves revamping instructional strategies to incorporate more hands-on practice and real-world applications, cultivating a positive attitude towards physics through engaging content, providing targeted support to enhance both procedural and conceptual understanding, and optimizing the learning environment to minimize distractions. By adopting such an integrated approach, educators can tailor interventions to address cognitive and non-cognitive barriers effectively, thereby fostering improvements in students' problem-solving skills and overall performance in physics.

This convergence is further supported by students' reflections, which align with their improved post-test performance. Participant 17 remarked, "*The part of the lesson I liked most was solving distance because it's enjoyable… you just multiply it and you get the answer*," indicating increased confidence and clarity in applying formulas—skills assessed in the quantitative strand. Similarly, Participant 5 noted appreciation for "*the introduction of various activities*," reflecting heightened engagement and motivation, both of which are associated with improved cognitive performance. These perceptions align with the significant increase in mean scores, from 17.35 to 32.88, suggesting that students' positive learning experiences translated into measurable academic gains.

In addition to performance improvements and favorable attitudes, students demonstrated a notable shift in their problem-solving strategies, particularly in addressing one-dimensional motion. During focus group discussions, many consistently described applying the formula $d = vt$ (distance = velocity × time) using systematic steps: identifying known variables, selecting appropriate equations, substituting values, and converting units when necessary. This shared approach indicates not only conceptual understanding but also the internalization of a structured method aligned with the instructional goals of the 5E model. The recurrence of these strategies, especially in solving straightforward problems, reflects collective conceptual mastery rather than isolated improvement, affirming the intervention's effectiveness.

Moreover, the convergence of the post-test mean score (M=32.88) and the outcomes of the post-intervention interviews suggests that the teaching intervention using the 5E Learning Approach has had a beneficial effect on both students' problem-solving abilities and their overall approach to learning. The higher post-test mean score suggests an improvement in students' proficiency in solving physics problems following the intervention. The qualitative data from the post-intervention interviews further support this improvement.

Beyond the observed improvement in test scores and favorable student perceptions, a notable convergence in students' problem-solving approaches emerged during post-intervention focus group discussions. Many students independently described following similar steps when solving problems involving one-dimensional motion: identifying known variables, selecting the appropriate formula (e.g., $d = vt$), substituting values, and performing unit conversions when necessary. This consistency suggests a shared internalization of problem-solving strategies introduced through the 5E learning model. It also indicates that students were not only memorizing procedures but developing a structured framework for tackling unfamiliar problems—aligning well with the competencies assessed in the post-test.

Such convergence in reasoning patterns reflects a shift toward more expert-like behavior in problem-solving, where students begin to recognize and apply underlying physics concepts systematically. The recurrence of these strategies among diverse learners in a heterogeneous class highlights the potential of the 5E model to promote not just individual gains but collective conceptual mastery. This alignment between students' problem-solving processes and the targeted learning outcomes reinforces the effectiveness of the intervention and emphasizes the value of structured, inquiry-based instruction in developing core scientific competencies.

Moreover, students expressed appreciation for problems that involved simple and straightforward calculations which indicates that they found these tasks enjoyable and manageable. Additionally, a significant number of students enjoyed lessons that included diverse and engaging activities. This reflects the effectiveness of the 5E learning model, which emphasizes hands-on, interactive learning experiences. Such activities enhance student engagement and motivation, contributing to their overall positive experience with the lessons. Therefore, by incorporating clear and manageable tasks along with diverse and engaging activities, educators can effectively enhance students' interest, confidence, and proficiency in physics problem-solving.

It can be observed, however, that 2.50% of participants remained at a low proficiency level in the post-test. This likely reflect persistent challenges identified in Figure 2, particularly within the student-focused and subject matter-focused dimensions. These include difficulties in procedural understanding, negative attitudes toward Physics, weak mathematical foundations, and lack of motivation—all of which may not be fully addressed by a single intervention cycle.

Future research may explore extended or repeated implementations of the 5E learning model, integrating targeted remediation strategies such as differentiated instruction, math skill reinforcement, or one-on-one tutoring. Additionally, longitudinal studies could better capture the sustained impact of the model on problem-solving proficiency over time. This study was limited to a single public rural high school and involved a relatively small sample, which may affect the generalizability of the findings. Further investigations across diverse educational contexts and larger populations are recommended to validate and expand upon these results.

CONCLUSIONS

The study highlights a range of challenges affecting students' proficiency in physics problem-solving. These include subject-matter challenges, such as foundational deficiencies and the computational complexity of physics; student-related challenges, such as cognitive and behavioral barriers; instruction-related challenges, including limited contextual application; and external factors, such as the physical and social learning environment. Despite these barriers, the implementation of the 5E Learning Approach proved effective in mitigating these issues. The significant improvement in post-test scores and positive student feedback highlight the value of interactive, hands-on learning and engaging activities. This approach not only enhanced students' problem-solving skills but also cultivated their interest and confidence in physics. These findings emphasize the need for a holistic instructional strategy that integrates practical applications, targeted support, and diverse, engaging learning experiences to improve student outcomes in physics.

The intervention was implemented over a limited period, which may not have been sufficient to fully address deep-seated cognitive and attitudinal barriers among some students. Despite its limitations, this study provides valuable insights into the effectiveness of the 5E learning model in enhancing students' problem-solving skills in Physics. The findings highlight the importance of student-centered, inquiry-based instructional strategies in fostering deeper conceptual understanding and engagement in science education. More broadly, the study highlights the need to address foundational skills, learning attitudes, and instructional relevance to better support students in mastering complex scientific concepts. Integrating models like 5E in teacher training and curriculum design could contribute to more effective science instruction, particularly in underserved and diverse learning environments.

Future research may examine longer or repeated applications of the 5E model, incorporating targeted support like differentiated instruction or math reinforcement. Longitudinal studies are also needed to assess its lasting impact. As this study was limited to one rural school with a small sample, broader studies in varied contexts are recommended to validate and extend the findings.

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