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Enhancing the Performance and Interest of Physics Learners in Kinematics Through the Application of Problem-Solving Techniques and Regular Classroom Tests at Swedru Senior High School

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Abstract Most Ghanaian physics students' performance in kinematics has been on the decline. Physics students in Senior High Schools in the Central Region are no exception. In this study, problem-solving techniques and routine classroom assessment were employed to improve Swedru Senior High School Physics students' performance and their interest in kinematics and physics at large. There were 53 participants in the research; 26 females and 27 males. Convenient sampling was used in the selection of the class. The mean scores of the pre-test and post-test showed that the students' academic performance had been improved by the problem-solving and regular classroom test teaching strategies that were implemented during the intervention stage. This is evident in the comparison of the mean values (pre-intervention = 4.56 and post-intervention = 11.96). The study also revealed the effectiveness of the intervention in arousing students' interest in kinematics. Students found learning kinematics to be more fun with the intervention deployed. The study's findings suggest, among other things that, teaching challenging physics concepts at the senior high school in Ghana should include problem-solving techniques and classroom test methods.

Keywords: *Ghana, problem-solving strategies, regular classroom tests, academic performance, kinematics*

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1. Introduction

Physics is viewed as applied mathematics due to its demand for mathematical computation [1]. Due to this, most physicists viewed problem-solving skills as the heart of physics. Although problem-solving skills are viewed as essential in the study of physics, many students lack the requisite skills [2]. Problem-solving has made physics to be considered one of the most difficult subjects [3]. Problem-solving is defined as the ability of learners to apply principles laws and theories to solve problems [4]. That is for the student to effectively solve problems related to physics, he or she is at least expected to understand the concepts, theories, and laws that govern the subject matter. For instance, quoting the formula of force and not knowing the meaning of individual parameters in the formula makes it difficult to understand the question. Problem-solving, according to Ince (2018), requires people to construct knowledge to cope with difficulties and may require the use of some strategies to remove undesirable situations. Problem-solving skills and understanding of concepts complement each other. Problem-solving skills are, therefore, the ability of students to apply the concepts learned in physics in solving a problem in physics. That is, for students to be able to solve physics problems, they are expected to have a good understanding of the concepts [5]. Problem-solving skill is one of the essential skills required of a physics teacher [6]. For students to develop their problem-solving skills, it is expected that their critical thinking domain must be developed first [7]. Some of these skills include a known problem, collecting information to surmount the problem, searching for solutions, testing the suitability of these solutions, choosing the most suitable solution, and assessment of the solution to the problem [25]. Recently, it has become the order of the day as most students have chosen to rather memorise formulas and, in the process, pay less attention to the conceptualisation and understanding of concepts. Many studies have been carried out to investigate the reason why students have problem-solving challenges. For instance, [8] investigated how the problem-solving performance of high school students differed after they used problem-solving strategies in cooperative groups in physics classes. The study utilised a five-step problem-solving strategy. A total of two hundred and nine (209) students were sampled with ninety-one (91) students previously practicing problem-solving in collaborative groups on their own, while one hundred and eighteen (118) students implemented this practice in cooperative groups. In this study, a six-step problem-solving strategy scoring rubric was used as the measurement tool. The outcome of the study revealed that the students who were in the experimental group and also utilised problem-solving strategies in cooperative groups showed higher performance in problem-solving. In addition to this, it was stated that contextually rich problems improved the conceptual learning of students [8]. With all the research done on problems solving, there are more gaps to be filled. The study, therefore, seeks to improve students' problem-solving skills as well as their interest in Kinematics. The revelation from the study could catalyse solving physics problems with interest by students and be the basis for further research in physics. Batlolona, Baskar, Kurnaz and Leasa [9] investigated the improvement of problem-solving skills and physics concept mastery on temperature and heat. Twenty-two (22) students were sampled and the instrument utilised was a teacher-made test. Paired sample t-test was utilised in analysing the data. The study revealed that students' performance in problem-solving skills increased from 40.68% to 74.77% while their mastery skills also saw a trajectory rise from 48% to 72%. Jua [10] investigated the profile of students' problem-solving skills in physics across interesting programmes in secondary schools in Indonesia. The research was descriptive research with a questionnaire and a test being the data collection tool utilised. The study revealed that students' problem-solving skills were low hence the reason for students' abysmal performance in physics. Furthermore, Ambaryani and Putranta [11] concurred with the same assertion, when they investigated improving learners' metacognitive skills with self-regulated learning based on problem-solving in science. Quasi-experimental with pre-test and post-test methods were utilised in the collection of data. The instrument used was a test in the form of an essay question sheet and a non-test in the form of a self-regulation journal and student observation sheets. The data revealed that problem-solving based method affects students' performance. From the Chief Examiner's Report [12] the performance of Ghanaian students in physics has been abysmal. Many students shun away from science-related programmes, especially physics at the tertiary level since it is viewed through the lens of being a difficult programme [13,14]. The problem is not only peculiar to Ghana's situation, for instance, South Africa the only representative country from Africa in the third International Science and Mathematics competition was adjudged the worst performer [15]. Although African students are the worst in performance when it comes to physics, it does not imply that developed countries are spared from the menace. The menace prompted the United States of America to commit resources to improve the performance and conceptual understanding of physics [16]. Physics, like any subject, would have been easier if students were expected to regurgitate formulas and facts only, the responsibility that comes with students applying these facts and principles in solving mathematical problems and relating them to the real world makes it burdensome for students [17].

Responsibilities rest on teachers to find the right pedagogy that will help students to assimilate concepts from general to specific, and concrete to abstract. Pedagogies utilised by teachers in senior high schools are the main reason for students' difficulty in understanding concepts in the study of physics [18]. Many female students shun away from studying physics. The enrolment of females in the study of physics in senior high schools is even worse as many females avoid physics like a plaque [19,20]. The big question is how do we change the narrative?

Teachers are expected to exploit innovative pedagogies that will arouse students' interest in problem-solving, leading to the solving of real-world problems [21]. Most students will still have doubts as to why they should solve complicated mathematical problems if they cannot utilise them in dealing with real-world problems. Students will appreciate learning physics if they feel the impact of it on their society [18]. Students' ability to have the confidence to tackle or solve a problem relies mostly on the teachers' pedagogy utilised in the classroom. This goes on to reveal the importance of teachers in the development of students' conceptualisation and understanding of solving problems in physics.

This study is based on the argument that no matter the pedagogy utilised by teachers in physics education, to improve students' academic performance, there is a need to help students build a proper foundation to acquire problem-solving techniques after their conceptual understanding. This can be achieved by regular exercises and classroom tests which in the end will help students in their preparation to sit their final examination. The government of Ghana in 2017 invested in our senior high schools with the hope of increasing our human resources. Senior high school education has even been made free in Ghana. It was of the view that students' performance in science by now would have improved. Contrary data has revealed otherwise [14]. For instance, the WASSCE results in recent years of Swedru Senior High School especially in 2020 revealed that only 22.8% scored A1-B3 [12] in Physics. This was also echoed in the Chief Examiners report which suggested that most students offering physics have poor conceptualisation and understanding of physics. It was also highlighted in the same report that, problem-solving under kinematics was one of the areas students had challenges [22]. Kinematics plays a crucial role in the engineering sector; hence it is a worry if the next generation of engineers are struggling to come to terms with physics concepts, then where lies the future of the country? The researcher decided to pilot and find out the cause of the problem and suggest possible solutions to the problems. At Swedru Senior High School, Form Two (2) science students were given an essay-type test on Kinematics to ascertain their performance of the students. After the test, it was discovered that most of the students performed poorly. The researcher observed physics teachers delivering lessons in the classroom and realised most of the teachers utilised the traditional method of teaching. It was also discovered that the only form of assessment of students was based on semester examinations conducted once every semester. The study aimed to improve the academic performance and interest of physics (science) students in kinematics using problem-solving strategies and regular classroom tests at Swedru Senior High School.

2. Methodology

The study aimed to improve students' problem-solving skills and their learning of some concepts in kinematics, hence action research design was utilised. Twenty-seven (27) males and twenty-six (26) female students were conveniently sampled for the research. In total, 53 second-year physics (science) students from Swedru Senior High School participated in the study. All eight weeks were used for the study. The students were made to answer the pre-test in the first week as the pre-intervention test. After the pre-intervention follows the intervention. The intervention was the approach used to help students enhance their performance and interest in the topics under kinematics, from the 2nd week to the 7th week. Students were taught for six weeks and were required to solve numerous problems under the topic treated under kinematics at the end of each week. The post-intervention stage followed the intervention stage in the 8th week. At this stage (post-intervention) students were made to and the post-test similar to the pre-test and the questionnaire items on students' interest in kinematics.

Weekly lesson plans were developed for the Senior High Schools Physics curriculum for the second term. Problem-solving techniques (outlined below) about kinematics were systematically developed and incorporated during the teaching and learning process. The weeks and the topics treated are shown in Table 1.

Table 1. Weeks and their corresponding topics in kinematics

Week	Kinematics Topic	
1	Pre-test	Test
2	Distance and Displacement	
3	Speed and Velocity	
4	Average Speed/Velocity & Instantaneous Speed/Velocity	Teaching of the content of Kinematics
5	Constant Speed/Velocity & Changing Speed/Velocity	
6	Acceleration and Direction of Acceleration Vector	
7	Constant and non-constant Acceleration, and Curvilinear Motion	
8	Post-Test and Answering of Questionnaire	Test and Questionnaire

During the intervention stage, the problem-solving approach was used in the following form:

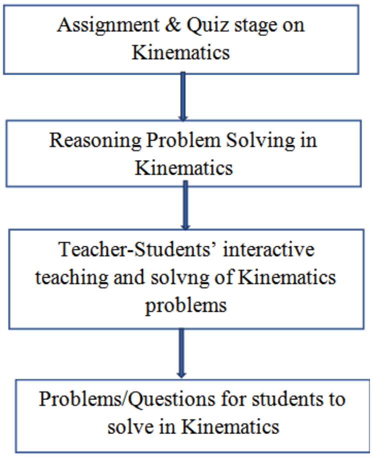


Figure 1. Intervention stage

For example, in Week 2, where the intervention began, the topic was on Distance and Displacement. Students usually assume distance to be the same as displacement. So in the previous week (the first week), students were to given assigned to read about the distance and displacement before the beginning of Week 2. This was necessary as students were supposed to use about 30 minutes to answer a short quiz on distance and displacement. The questions were as follows:

1. What is (i) distance? (ii) displacement?
2. Write down the main difference between distance and displacement.
3. Kofi drives his vehicle 300 km North but then turns back South for 115 km to pick up a friend.

a) Calculate the distance covered by Kofi.
b) Find the magnitude of the displacement of Kofi.

After the short quiz, students were provided with reasoning problems to discuss in groups of 4 students. Examples of the reasoning questions given to students were:

1. A lady student leaves the physics laboratory and walks 15 metres north to a drinking fountain. Then she turns and walks 20 metres south to the Chemistry laboratory. a) What is the lady's total distance from the Physics Laboratory to the Chemistry laboratory? b) What is the lady's total displacement from the Physics Laboratory to the Chemistry laboratory?

2. Ama walks from the point A to B to C. What is the distance she walks? What is the displacement of Ama?

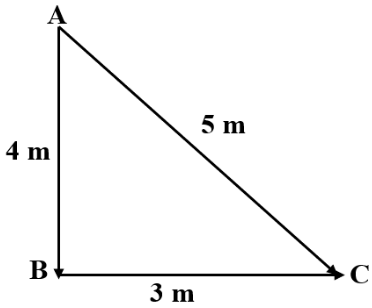


Figure 2. Path covered by Ama

This session was to encourage students to reason and exhibit their conceptual understanding skills to solve problems. This session takes about 60 minutes.

The next session is the Teacher-Students' Interactive teaching and solving problems on Kinematics problems. This session allowed the instructor to guide students on how to solve problems on distance and displacement using questions. For example, teacher interacts with students with examples on distance and displacement.

Distance is a scalar quantity representing the length of the path taken. However, Displacement is a vector quantity and can be defined as the shortest interval including the direction as the crow's flight. It must be the shortest interval connecting the initial and final points, that is a straight line.

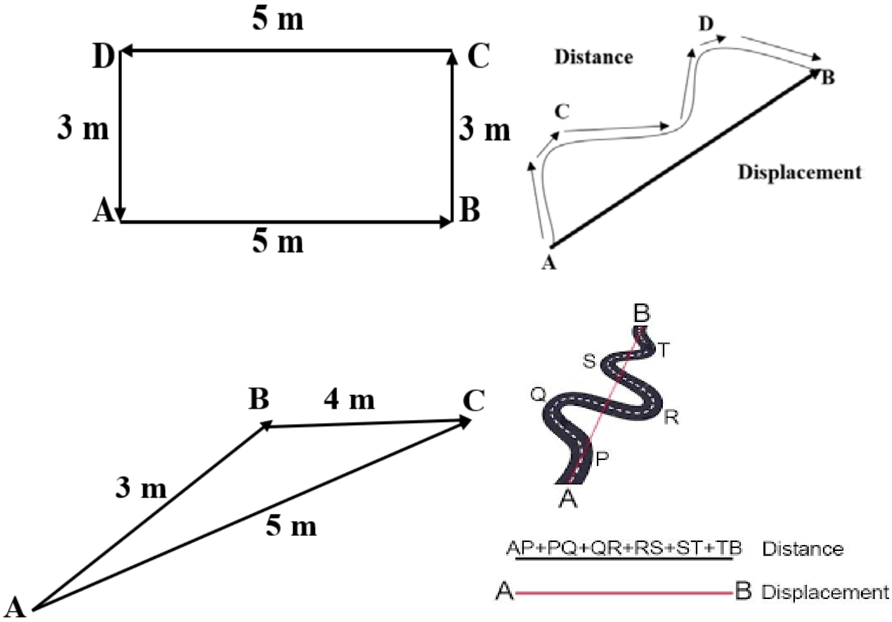


Figure 3. Different paths covered

After this session, students are given problems/questions on kinematics to solve. This session is called the Problems/Questions for students to solve on Distance and Displacement. They are first allowed to apply the conceptual understanding that they had gained to answer the short quiz and the reasoning questions before some related or application problems/ questions are given to students to solve as weekly test items. Samples of the application questions are as follows:

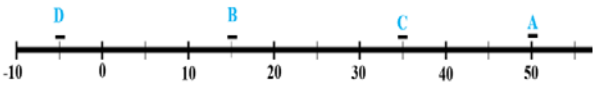
If Daniel wants to drive home from where he is now, the road first takes him 50 km East, and then 70 km North.

(a) Compute his overall displacement.

(b) His BMW car uses 1 litre of fuel for every 10 km. Daniel is short of money and needs to borrow some money from his wife who is also in the car. How much money would he need to borrow to buy the fuel that can take them home?

(1 litre= 1.50 GH cedis).

A football coach paces back and forth along the sidelines. The diagram below shows several of the coach's positions at various times. At each marked position, the coach makes a "U-turn" and moves in the opposite direction. In other words, the coach moves from position A to B to C to D. What is the coach's resulting displacement and distance of travel?



Similarly, these steps were followed for the rest of the topics under kinematics for every week. Students were encouraged to also follow as much as possible the following techniques/procedures to help them gain a better understanding of solving problems/questions.

Problem-solving techniques [23]

Strategy design

Classify the problem by its method of solution.

Summarise the situation with a diagram.

Keep the goal in sight (perhaps by writing it down).

Execution tactics

Use symbols in your work.

Keep related variable packets together.

Maintain a nice and orderly appearance.

Keep it straightforward.

Answer checking

Dimensionally consistent?

Numerically reasonable (including sign)?

Is Algebraically possible? (Example: no imaginary or infinite answers.)

Functionally reasonable? (Example: greater range with greater initial speed.)

Check special cases and symmetry.

Report numbers with units specified and with reasonable significant figures.

The instructional objectives to be achieved each week were set and outlined. The lesson plans incorporated the test items to be administered for the week. Test items that were used in the weekly tests were constructed based on the activities and concepts that were treated within the week and the previous weeks. The test items consisted of essay-type questions. An essay type was chosen because it measures complicated learning outcomes and also stresses the integration and application of thinking and problem-solving skills as shown earlier in the example of teaching and learning of Distance and Displacement. According to Davis [24], students preparing for essay tests focus on general concepts, broad issues, and interrelationships rather than on specific details, and this results in better students' performance as well as improved problem-solving skills. These test items were piloted at a nearby senior high school named Swedru Business High School to check the validity of the test items. The reliability of the Likert scale questionnaire items has a Cronbach alpha value of 0.8. This showed that the questionnaire was reliable. Based on their responses to questions in weekly tests and during lessons, students' outputs were evaluated to ascertain if their explanations indicated comprehension of the ideas learned. The results of this series of observations were utilised to modify and adjust the interventional strategies to attain the intended problem-solving and learning objectives. Teacher-made tests and questionnaires were utilised in the collection of data. The pre-test and post-test were similar in structure and content. A five-point Likert scale questionnaire with eight items was distributed to students after the intervention to solicit their interest relating to the effectiveness of the intervention.

3. Results and Discussions

Age of Students

The age of students was grouped as 14-16 and 17-18 and presented in Table 2.

Table 2. Age of Students

Age (years)	Frequency	Percentage (%)
Age 14 – 16	20	37.7
Age 17 – 18	33	62.3
Total	53	100.0

Table 2 revealed that the majority of the fifty-three (53) students were between the ages of seventeen (17) and eighteen (18), accounting for 62.3% of the total, while the remaining students were between the ages of fourteen (14) and sixteen (16), accounting for 37.7%. This indicates that the majority of the students were within the standard academic age range of 15-17 years.

Gender of Students

The gender of students according to this study was classified as males and females and presented in Table 3.

Table 3. Gender of students

Sex	Frequency	Percentage (%)
Male	26	49.1
Female	27	50.9
Total	53	100.0

From Table 3, the class under investigation was dominated by females. Out of the total of the 53 students, 27 (50.9%) were females while 26 (49.1%) were males. Ever since the introduction of science as a course into the second-cycle educational system of Ghana, the enrolment of males has always been high but this seems to be an improvement in female dominance in the study of science in senior high schools.

Mean proportion correct score on a classroom test

The weekly mean proportion correct scores of students on classroom tests are presented in Table 4.

From Table 4, it was revealed that students' academic performance improved as the weeks progressed. For instance, the first test in week 3 had a mean proportion of 4.59, while the second test which was written in the 5th week had a mean proportion of 6.39, and also, the third test which was written in the 7th week had a mean of 10.91. The result showed a gradual improvement in students' performance as the weeks progressed. The results affirmed the assertion made by [5] that regular exercises improve students' academic performance.

Table 4. Mean proportion correct score on a classroom test

Week	3	5	7
Mean score	4.56	6.39	10.91

Students' mean values of pre- and post-intervention tests

Students' mean values of pre- and post-intervention tests were presented in Table 5.

Table 5. Students' mean values of pre and post-intervention tests

	N	Mean	Std. Deviation	Std. Error Mean
Pre-test	53	4.51	2.929	0.402
Post-test	53	11.96	3.919	0.538

Table 5 revealed a mean of 4.51 (sd-2.929) for the pre-test and 11.96 (sd-3.919) for the post-test questions. This data reveals that there is a notable improvement in students' performance after the intervention.

Paired sample t-test on students' pre-test and post-test mean scores

To find out whether the improvement in terms of their mean scores was statistically significant, a paired-sample t-test was conducted and the result was shown in Table 6.

Table 6. Paired sample t-test on students' pre-test and post-test mean scores

	N	Mean	Std. Dev.	Std. Error Mean	t	df	p
Pretest-Posttest	53	-7.45	4.24	0.58	-12.795	52	0.001

From Table 6, the paired sample t-test was conducted to evaluate whether a statistically significant change occurred between the mean scores of the pre-test and post-test. The results showed that there was a statistically significant difference, [$t = -12.795$, $p<0.05$], hence the intervention used did improve students' performance in kinematics.

Mean proportion of students' performance in terms of gender

The mean proportion of male and female students' performance was conducted and the result was shown in Table 7.

Table 7. Mean proportion of students' performance in terms of gender

Test	Student's Gender	N	Mean	Std. Deviation	Std. Error Mean
Pre-test	Male	26	5.10	3.118	0.611
	Female	27	3.94	2.672	0.514
Post-test	Male	26	12.50	4.219	0.827
	Female	27	11.44	3.611	0.695

Table 7 revealed the difference in the performance of male students and their female counterparts at Swedru Senior High School. It was revealed that the mean score for male students in the pre-test was 5.10 (sd-3.118), while their female counterpart was 3.94 (sd-2.672). The results reveal that males' performance dominated their female counterparts. A similar observation was made in the post-test results where the mean score of the males was 12.50 (sd-4.219), while the females had a mean of 11.44 (sd-3.611).

Although there was an improvement in performance in both groups for their pre-test and post-test mean results, the results were further tested to find out whether there was a statistically significant difference between the males and females for their pre-test and post-test values. These were presented in Tables 8 and 9.

Tables 8 and 9 present the outcomes of paired-sample t-tests that compared the mean scores of pre-test and post-test results between males and females. Table 8 shows the outcome of the paired-sample t-test for the male and female students' pre-test mean scores. The difference in mean and standard deviation of the pre-test scores between males and females were 1.23 and 4.97 respectively with a standard error mean of 0.97. The t-value was 1.263 and the p-value associated with this was 0.218. Because the p-value was more than 0.05, it is implied that there was no statistically significant difference in the pre-test mean scores of males and females. Thus, the male and female students who participated in the study were of equal strength in knowledge of Kinematics before using the intervention.

Similarly, Table 9 also displayed the results of the paired-sample t-test for the male and female students' post-test scores. The difference in mean post-test score was 1.19 with a standard deviation and error mean of 5.21 and 1.02 respectively. The t-value was 1.167 and it is associated with a p-value of 0.254. The p-value is also more than 0.05, hence there was no statistically significant difference in the post-test mean scores of male and female students. Thus, the impact of the use of Problem-Solving Techniques and Regular Classroom Tests on 53 second-year male and female physics (science) students from Swedru Senior High School in the teaching of kinematics was still the same. It can therefore be concluded that the use of Problem-Solving Techniques and Regular Classroom Tests favoured both genders.

Table 8. Paired-sample t-test of gender pre-test mean scores

	N	Mean	Std. Deviation	Std. Error Mean	t	df	p
Pretest Male - Pretest Female	26	1.23	4.97	0.97	1.263	25	0.218

Table 9. Paired-sample t-test of gender post-test mean scores

	N	Mean	Std. Deviation	Std. Error Mean	t	df	p
Posttest Male - Posttest Female	26	1.19	5.21	1.02	1.167	25	0.254

Table 10. Comparing students' responses on their interest in kinematics (physics) teaching and learning concerning how they view their skills and abilities

	Items	Strongly Disagree (n) %	Disagree (n) %	Neutral (n) %	Agree (n) %	Strongly Agree (n) %
a.	I look forward to eagerly anticipating interesting kinematics lessons compared to before the start of the project.	3 6.0	4 7.5	14 26.4	23 43.4	9 17.0
b.	Kinematics lessons in class are fun compared to before the start of this project.	7 13.2	11 20.8	11 20.8	14 26.4	10 18.9
c.	Kinematics practical lessons in the laboratory are fun compared to before the start of this project.	19 35.8	14 26.4	12 22.6	4 7.5	4 7.5
d.	The lessons made me interested in kinematics compared to before the start of the project.	7 13.2	6 11.3	12 22.6	16 30.2	12 22.6
e.	I understand kinematics theories before solving physics problems compared to before the start of the project.	10 18.9	12 22.6	12 22.6	15 28.3	4 7.5
f.	I solve more problems by focusing on its main points compared to before the start of the project.	10 18.9	12 22.6	9 17.0	14 26.4	8 15.1
g.	I can apply theories in solving questions in kinematics compared to before the start of the project.	12 22.6	13 24.5	9 17.0	15 28.3	4 7.5
h.	I can apply mathematics in solving questions in kinematics compared to before the start of the project.	8 15.1	7 13.2	7 13.2	16 30.2	15 28.3

Many inferences were drawn from Table 10, for instance, Table 10 revealed that 32 students representing 60.4% looked forward to interesting kinematics lessons compared to 13.5% before the start of the intervention with 26% not certain about their decision. Likewise, 45.3% of the students agreed that kinematics was more fun compared to 34% who disagreed with the assertion. The remaining 20.8% were neutral in their decision. This reveals that the use of problem-solving skills aroused students' interest and it further reveals that students' interest in physics will improve if the right pedagogies are implemented. This was backed by the number of students who were interested in problem-solving skills used as the intervention. The number of students interested in kinematics (physics) due to the intervention introduced was encouraging as 52.8% of the students were found to support the notion, while 24.5% thought otherwise with 26.3% deciding to stay neutral. The results drew the attention of the researcher that although many students' performance increased over the seven (7) weeks, many students still struggled to understand theories before answering the questions. About 41.5% of the students believed that they struggled to understand theories before answering questions, while 35.8% suggested otherwise, with the remaining 22.7% decided to stay neutral. Notwithstanding, 41.5% of the students believed they could now solve more problems in kinematics by focusing on its main points compared to before the start of the project with the same number of students disagreeing. It is worth noting that after the intervention, 35.8% of the students understand kinematics (or physics) theories before solving kinematics (physics) problems. This was confirmed by the number of students (35.8%) who agreed that they could apply theories in solving problems with 41.5% suggesting they still struggled to apply theories in solving questions. This trend reveals that more efforts are to be made to ensure that students can apply theories in solving problems. It was encouraging to know that 58.5% of the students were able to manipulate mathematical equations in solving physics problems as opposed to 28.3% with 13.2% of the students remaining neutral in their decision.

4. Conclusion

The study revealed the effectiveness of incorporating regular classroom tests into problem-solving skills. The study revealed that the performance of the post-test results of the students increased significantly as shown in Table 5, where the mean score for the post-test was 11.96 as opposed to a pre-test mean score of 4.56. The study also revealed the effectiveness of the intervention by arousing students' interest in the learning of kinematics in physics. It was interesting to know that students were finding the learning of physics to be more fun as compared to before the intervention. It is worth mentioning that there were a quite number of students who were struggling to apply theories in solving physics problems, nevertheless, students' application of the mathematical concepts in solving physics problems was encouraging. Notwithstanding, the intervention used was found to be effective in improving students' performance in kinematics and hence recommended to tackle similar problems in physics.

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