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Improving physics problem solving skills of students of Somanya Senior High Secondary Technical School in the Yilo Krobo District of Eastern Region of Ghana

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Abstract

The main objective of the study was to improve the problem solving skills of physics students and for that matter increase their interest in physics and science at large. The main instrument used to collect data was test items. The test items consisted of pre-test and post-test items. A population of 16 students was involved in the study. Duration of four weeks' intervention plan with the class using an innovative method of teaching problem solving strategy was employed. The data collected from pre-test and post-test were analyzed using frequency counts and percentages. The post-test analysis manifested that there had been an improvement in the way students solve physics problems. The perception of the students that physics is too difficult appeared to have waned. Students who once feared solving physics problems now ask for more exercises and assignments after the lesson has been taught.

Key words: Physics problem solving skills, West African Examinations Council, metacognition, heuristics, Competent Problem Solver Method, understanding basic mechanics method, experts and novices' approach to problem solving, action research.

1.0 Background to the study

In Ghana, relatively few students take physics as an elective subject at the Senior High School level although, as Piaget (1977) would suggest, young adolescents have the cognitive abilities to master concepts in Physics. According to Piaget (1977), cognitive development proceeded in four qualitatively different stages. The last stage, formal operations, is typically reached after about the age of 11 years. During this stage, adolescents' thinking becomes abstract and symbolic and they develop reasoning skills and a sense of hypothetical concepts. Thus, Senior High School students, whose average age is about 16-18 years, should have the cognitive abilities, experience and knowledge in problem solving abilities to account for differences between experts and novices.

Problem solving involves at least three dimensions: (a) domain knowledge, (b) problem-solving methods, and (c) characteristics of problem solvers (Ronning, McCurdy& Ballinger 1984). First, rich domain knowledge (knowledge schema) allows experts to classify problems more readily and thus guide their solutions in a more efficient and skilled way. Because novices tend to lack such a developed schema, they are more likely to search in an undirected fashion for a solution. Second, evidence suggests that junior high school students do not profit from a general problem-solving strategy (Ronning *et al*. 1984). Rather, they may benefit more from a hands-on approach to teaching science. Good problem solvers tend to gain from personal experience and general knowledge, from being able to use analogies, and from metacognitive skills. The problem with most Physics teachers is that they hope to impart knowledge that can be applied to situations other than those that were directly taught. This objective is tempered by persistent results of studies showing that experience with particular problems often yields little or no transfer to similar problems.

Successful physics students are those students who understand complex physics formulae in basic terms (Sherin 2001). Understanding the fundamental building blocks of physics and being able to transfer them to understand complex formulas permits students to gain the understanding and flexibility necessary for transference of knowledge to other problems in physics. Research on Newtonian mechanics problem solving suggests that undergraduate students can be adept at solving traditional quantitative physics problems while still having an extremely poor conceptual or qualitative understanding of the principles involved (Halloun & Hestenes 1985).

Physics by its very nature is exceptionally quantitative. It teaches students to try to reduce problems to exercise already in memory or available from outside sources. Thus, it is concerned mainly with determining what 'recipe' to use in solving a problem. Students are first taught a number of important "paradigm" problems and given enough training in their use that, the paradigm problems become exercises. When presented with a physical situation, the students are instructed to construct a model of the situation; the simplest description which adequately describes the problem. Once the problem has been modeled, the student chooses which exercise in his or her textbook is best for solving it. In short, what it means is that, when a problem is given, figure out what kind of physics you need to solve the problem, and solve it. Deceptively simple, it is what experts do. The real work begins with finding a way to train students in this. While a great majority of daily experience involves problems that can be solved by referring to what is known already, not all problems can be solved this way. Problem solving is an instructional method, where students are allowed unlimited opportunities to demonstrate mastery of content taught. This involves breaking down the subject matter to be learned into units of learning, each with its own objectives. The strategy allows students to study material unit after unit until they master it (Dembo 1994). Mastery of each unit is shown when the student acquires the set pass mark of a diagnostic test. Hence the method helps the student to acquire prerequisite skills to move to the next unit. The use of Problem solving in teaching Physics in senior high schools is likely to help improve their academic achievement. Also, in most researches in introductory-level science education, it has been realized that for students to gain conceptual understanding, the instructor must teach conceptual understanding to focus on what concepts students have of the world around them, and on finding ways to bring these concepts in line with those held by physicists (Van Demelon 2008). According to Bogdanov & Kjurshunov (1998), as far as education and teaching are concerned, problem solving is one of the best ways to involve students in the thinking operations of analysis, synthesis and evaluation which are considered as high-order cognitive skills. This is the purpose of this study, which intends to add to the body of knowledge on how problem solving skills could effectively be used to enhance students' understanding of concepts in physics in Ghanaian Senior High Schools.

1.1 Statement of the problem

One of the most continual problems in learning physics is the perceived difficulty encountered by students when solving physics problems. This persists due to students' lack of proper and effective methods to tackle these problems. Most topics in physics such as mechanics, optics, electricity and several others involve problems which can be solved simply and effectively using proper problem solving methods. The Competent Problems' Solver and Understanding Basic Mechanics are examples of proper problem solving methods. According to the West African Examinations Council (WAEC), the Regional body charged with organizing examinations in English speaking countries in the West African Sub-region, Chief Examiners' Report on WAEC West African School Certificate Examination (WASSCE) Physics Examination (2003-2006), physics is gradually phasing out and if care is not taken, it will be very difficult to get adequate competent teachers to effectively handle the subject. It appears there is a high negative impression that physics is too difficult and as such few students are pursuing it at various levels of academic discipline. Physics is perceived to be difficult due to lack of proper problem solving strategies. Specifically, most of the candidates had problems in: (i) data analysis in terms of drawing graphs to illustrate given physical phenomena; definitions and explanations of physics concepts; not being able to distinguish between the 'situation' in which certain physical phenomena occur and the 'uses' of such phenomena; failing to read the question very well before attempting to answer it; and weak mathematical background. The above mentioned observations concerning the study of physics have prompted this study to find out possible interventions to improve on the problem solving skills of physics students.

1.2 Research Questions

The following research questions guided the study.

1. Will the use of the competent problem solver and the understanding of basic mechanics methods of solving physics problems make students competent problem solvers?
2. Will the use of the competent problem solver and the understanding of basic mechanics methods of solving physics problems increase the interest of students in physics?

2.0 How to tackle and solve physics problems

Researchers in physics have come out with various ways of tackling and solving problems in physics, two of which are heuristic and metacognition.

2.1 Heuristic

A heuristic is a rule of thumb. It is a strategy that is both powerful and general, but not absolutely guaranteed to work. Simon, Langley & Bradshaw (1980) gave some examples of heuristics and these include "working backward." This heuristic suggests the problem solver to first consider the ultimate goal. From there, the problem solver decides what would constitute a reasonable step just prior to reaching that goal. Beginning with the end, the problem solver builds a "strategic bridge backward and eventually reaches the initial conditions of the problem". Heller & Hollabaugh (1992) opine that, two factors can help make one a better physics problem solver. He or she must first of all understand the principles of physics, and secondly, must have a strategy for applying these principles to new situations in which physics can be helpful.

2.2 Metacognition

Although heuristics helps a problem solver break down a problem into more manageable pieces, the challenge becomes one of managing the sub-goals. Davidson, Deuser & Sternberg (1994) regarded such goal management as a central feature of problem solving, and is an example of a more general phenomenon of self-monitoring known as ***metacognition***. Metacognition has been described in many ways. Flavell (1976, p.232) described metacognition as: "… one's knowledge concerning one's own cognitive processes and products or anything related to them. Metacognition refers, among other things, to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects on which they bear, usually in the service of some concrete goal or objective." It is not always easy to distinguish what is metacognitive and what is cognitive. One way of viewing the relationship between them is that "cognition is involved in *doing*, whereas metacognition is involved in *choosing and planning what to do and monitoring what is being done*" (Schoenfeld 1987). In general, the regulatory aspect of metacognition is concerned with decisions and strategic activities that one might engage in during the course of working through a problem. Some examples of such activities include selecting strategies to aid in understanding the nature of a problem, planning courses of action, selecting appropriate strategies to carry out plans, monitoring execution activities while implementing strategies, evaluating the outcomes of strategies and plans, and, when necessary, revising or abandoning non-productive strategies and plans.

2.3 Distinction between experts and novices approach to problem solving

Researchers have found that experts and novices differ considerably in their approaches to problem solving. This is consistent in all aspects of the problem-solving process. Expert problem solvers differ from novices in that they possess deep and connected domain knowledge that allows them to identify meaningful patterns in a problem situation (Bransford, Brown, & Cocking 2000). Novices, on the other hand, tend to focus on surface features while failing to establish connections between the different issues (Ertmer & Stepich 2005). According to (Ge & Land 2004, p. 5), ill-structured problems are "those that we encounter in everyday life, in which one or several aspects of the situation is not well specified, the goals are unclear, and there is insufficient information to solve them". Another difference between expert and novice problem solvers is in the evaluation of the problem-solving process. Experts appear not only to continually evaluate their progress when solving a problem, but also evaluate the final answer. These evaluation processes, such as considering limiting cases and checking units, are quite common in experts. Novices, on the other hand, do not tend to evaluate their progress, nor are they likely to evaluate their final answer. Successful problem solvers monitor and evaluate their actions and cognitive processes throughout the entire problem-solving process, whereas less successful problem solvers often do not.

2.4.0 The problem-solving framework

2.4 The Competent Problem Solver Method

The key component of these instructional strategies is the competent problem solver method is a five-step structured problem solving strategy as follows:

1. visualize the problem
2. describe the problem in physics terms
3. plan a solution
4. execute the plan
5. check and evaluate

2.4.1 Understanding Basic Mechanics Method

This method has three basic steps: **Analyze the Problem, Construct Solution,** and **Check (and Revise if need** be). The first and third steps are broken down into a list of questions the student needs to ask about the problem and factors that should be taken into account. The second step, the 'meat' of the method, concerns itself with finding appropriate sub- problems that resemble the exercises the students are already capable of working, or can easily figure out how to work. In constructing the solution, the student first determines what needs to be done: is there missing information? Are there unknowns that might be removed by proper combination of relations? Once that has been determined, the student is helped along the path to accomplishing the sub-goal. This method is a heuristic method, in that it teaches the student ways of thinking and learning. In constructing the solution, the student first determines what needs to be done by asking these self questions: Is there missing information? Are there unknowns that might be removed by proper combination of relations? Once that has been determined, the student is helped along the path to accomplishing the sub-goal. Among the two methods described above, it is considerably easier to work with **the competent problem solver method** in collaboration with **the Understanding Basic Mechanics Method** because of the following reasons: The Competent Problem Solver Method has rigorously shown to work in group settings where the total class size was small enough that the teacher could effectively manage the groups (Heller & Hollabaugh 1992). There are sixteen (16) physics students in Somanya Secondary Technical School; hence it was expedient to apply this method. Also the Competent Problem Solver Method is used since it teaches a general strategy with emphasis on the specific methods needed for physics problem-solving. This method helps overall problem-solving skills of students especially in the areas of focusing the problem and checking the results (Heller & Hollabaugh 1992). Secondly, problem-solving skills are often a limiting factor on students. They may understand the concept or think they understand it but are blocked by inability to do the problem itself. Researchers in various fields of science education have pointed out how students often seem to have great difficulty with problems that are simply concatenations of several exercises the students can already work (Bodner 1991). By improving the problem-solving skills of the student population, it may become easier to spot conceptual difficulties that the students have.

3.0 Methodology

3.1 Research design

This study is an action research aimed at improving the problem solving skills of Form Three physics students through the use of the competent problem solver method and the understanding basic mechanics method at Somanya Secondary Technical School. The study, being action research, offered the opportunity to engage in continuous cycles of *planning, acting, observing and reflecting,* which generally characterise action research approaches. McNiff & Whitehead (2002), elaborate on these cycles to describe spontaneous, self-recreating system of enquiry as a systematic process of *observe, describe, plan, act, reflect, evaluate, modify,* but they stress that the process is not linear, but transformational, which allows for greater fluidity in implementing the process. This systematic process could be presented pictorially in Fig.

3 1. The action research cycle is generally given as a four-step cycle of *reflect → plan → act → observe* (see Fig. 3.1). That is: *reflecting* on one's practice and identifying a problem or concern, *planning* a strategy or intervention that may solve the problem, *acting* or carrying out the plan, and finally, *observing* the results or collecting the data. It is common for practitioners to follow the observation phase with reflecting anew, planning and carrying out another intervention, and, again, observing the results, continually repeating the cycle, continually seeking improvement (Higher Education Academy 2009).

3.2 The study setting

The research was conducted at Somanya Secondary Technical School in the Yilo Krobo District in the Eastern Region. The school is located at Somanya, about 15km off the Kpong - Accra Road. The school has a population of eight hundred and seventy-five students which is made of 405 boys and 470 girls. The school currently runs courses in General Arts, Visual Arts, Science, and Home Economics.

3.3 Population for the study

The target population for the study was all science students in form three at Somanya Secondary Technical School for the 2010 to 2011 academic year. The entire form three science students were made up of sixteen (16) students with eleven (11) boys and five (5) girls at that time of the study. The reason why the study was centered only on Form Three science students was that, the school started to run science as a course just last two years (i.e. 2009) hence, there was no science class in Form Four. Also, from the new educational reform, Form One students offer only the core subjects so there were no science students in Form One.

3.4 Sample

The entire population of form three science classes was used since they were only sixteen (16) in numbers.

3.5 Instrumentation

The researcher used pre-intervention activities such as class works, tests and assignments and a post-intervention test to collect data for the study. Students were made to take a test which consisted of three questions in Kinematics after students were taught the concepts. A post-intervention test was conducted to serve as a check as to whether students really applied the methods and steps they were taught. This test also consisted of three items similar to items in the pre-test.

3.6.Intervention design

In order to help students to improve upon their problem solving skills in physics, an intervention design was planned out. Students were engaged in a comprehensive discussion on the steps involved when solving physics problems using the 'understanding basic mechanics' and the 'competent problem solver' methods, using their normal classroom hours, ***two hours per week*** for **four weeks**. After the discussion, a power point presentation on DVDs, containing the steps in solving physics problems was distributed to students. Students were taken to the computer room and each had a computer to himself/herself. They observed and learned the content including the steps involved in solving physics problems. Students were made to repeat the learning on the power point presentation once every week on their own. This was done such that students could be familiar with the steps needed for solving problems in physics. Marking of tests were strictly based on these steps. Those who did not apply the steps or jumped some steps when solving a problem lost some marks.

3.6.1 Implementation of the intervention

Below is a brief description of the steps followed when using the understanding of basic mechanics method and the competent problem solver method.

Step 1 – **Understand the problem**

To really understand the problem, the following sub-steps are needed to be considered.

a. Read the problem carefully.
b. Find the important information.

c. Write down the known values and the unknown values.
d. Identify what the problem wants you to solve.
e. Ask if your answer is going to be a larger or smaller number compared to what you already know. This is indicated below as a four step technique (see Fig. 3.2).

Step 2 – **Decide how you are going to solve the problem**

Decisions on how to solve the problem may depend on your choice of one of the following strategies.

Use a graph	Use formulas
Make a list	Find a pattern
Work backwards	Use reasoning
Draw a diagram	Make a table
Act it out	

However, in this study the strategy of ‘draw a diagram’ was used.

Step 3 - **Solve the problem**

Problem is solved by plugging known values into relations or formulas to solve for unknown value.

Step 4 **- Look Back and Check**

This is done by re-reading the problem and comparing the information from the problem to your work. After that, ask yourself this question, “Did I solve what the problem asked me to solve?”

In order to ensure that students go by these steps when solving problems, the following grading criteria were used to assess students on the steps as shown in Table 3.1 (*see Table 3.1*).

3.6.2 Post intervention activities

A post-intervention test was conducted after the implementation of the intervention activities.

The test was made up of three questions similar to the questions in the pre-intervention test (see Appendices A & B for the pre-intervention and post-intervention tests). Students’ responses to the questions were collected, marked and analyzed.

3.7 Method of data analysis

To ensure simple analysis of data for the study, the responses were put into frequency counts and then converted into percentages. The percentages were used to interpret the result.

4.0 Results and discussions

Tables 4.1 -4.3 below were used to interpret the students’ responses in the test conducted. The number of students obtaining a particular mark is placed in parenthesis against the mark and the percentage of students written below in the tables (*see Tables 4.1 -4.3*).

From all the tables above, averagely, only three (3) students (i.e. 19%) listed all the known and unknown values in a problem before solving it. The rest of the students (i.e. 81%) failed to list them. Also, it was noted that, on the average only four (4) student representing 25% made free body diagrams to simplify problems before solving them. The rest representing 75% failed to draw diagram and this led some of them to mess up with the right equations needed to solve the problem. Moreover, it was realized that averagely ten (10) students representing 62.5% could write the appropriate relations and formulas. This served as a proof of students being conceptually knowledgeable but lacked problem solving skills. On the average, eight (8) students (i.e. 50%) were finding it difficult to plug in values into equations and perform simple algebra to find answers to problems. This could be a result of their weak mathematical background.

As for the answer checking, it was done by considering two things. These were numerical reasonability and validity of the units attached to answers. From the data collected, it was found that, seven (7) students representing 44% gave reasonable answers in terms of number. The answers given by the remaining 56% of the students were totally out of range. The cause might be their failure to properly check and analyze their answers. Also, only five (5) students (i.e. 31%) were able to attach their answers with correct units. The remaining eleven (11) students (i.e. 69%) attached wrong units to their answers due to bad problem solving habit. Their aim probably was to arrive at the answer without thinking about how they came by the answers. Hence they jumped vital steps, and did serious omissions without showing workings.

4.1 Observations made before the implementation of the intervention

The following observations were made before the implementation of the intervention.

1. Students were found jumping vital steps without showing workings. They arrived at the final answer without caring about the procedures and steps needed to arrive at that answer. Hence they lost about half of the total marks for the question.
2. Those who were able to work to the final answer attached wrong units to them and some even ignored writing the units all together.
3. It was also observed that some students rushed into solving physics problems but got stacked along the way perhaps due to improper analysis before tackling the problem.
4. Students appeared to forget the steps needed to solve physics problems after they have been taught.

4.2 Post-intervention results

A post-intervention test was administered to students. The test was conducted to find out whether students really applied the 'understanding basic mechanics method' and the 'competent problem solver method' and the steps needed to solve problems in kinematics. The questions in this test were similar to those in the pre-intervention test (see Appendix B). The post-intervention questions were well attempted by students and the marks obtained have been tabulated and analysed below (see Tables 4.4 -4.6).

The result from the tables shows that majority of the students exhibited improved problem solving skills. The percentage of students obtaining the maximum mark for each step ranges from 75% to 100%. For instance, averagely, fifteen (15) students representing 94% listed all the known and the unknown values correctly and made reasonable free body diagrams before carrying on with the solution to the problems. This might be due to proper analysis made by the students of the problems before tackling them. Listing of the known and the unknown values and drawing reasonable free body diagrams perhaps simplified the problems. Hence many students were able to identify the right formulas and equations and were able to plug in values to solve the problems. Also, an average of fourteen (14) students representing 87.5% was able to identify and plug values into equations to solve the problems. Thirteen (13) students (i.e. 81%) on the average gave reasonable answers in terms of number. An average of fourteen (14) students representing 87.5% attached correct units to their answers.

From the above results, it can be concluded that students have really become competent in solving problems considering their performance in the post- intervention test.

5.0 Conclusion

The study revealed has revealed that after the implementation of the intervention, students' problem solving skills have improved considerably. This was manifested in how students presented their class exercises and assignments and how they went about solving problems given them. It appears students have developed interest in solving physics problems since they could remember and use the steps needed to solve the problems. Hence the perception of the students that physics is too difficult appeared to have waned. Students who once feared solving physics problems now ask for more exercises and assignments after the lesson has been taught. Problem solving in physics commonly involves the application of various mathematical procedures, so teachers should focus on proactive ways of presenting subject material so as to guide students' learning efforts, while students strive to become active, self monitoring constructors of knowledge. This way, the perceived difficulty of physics cannot overshadow its importance in terms of its usefulness in the society, and by implication increase students' interest in the subject which will automatically lead to increase physics enrollment in Ghanaian schools and colleges.

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Notes

Fig. 3.1. Action Research Cycle (From: McNiff & Whitehead 2002).

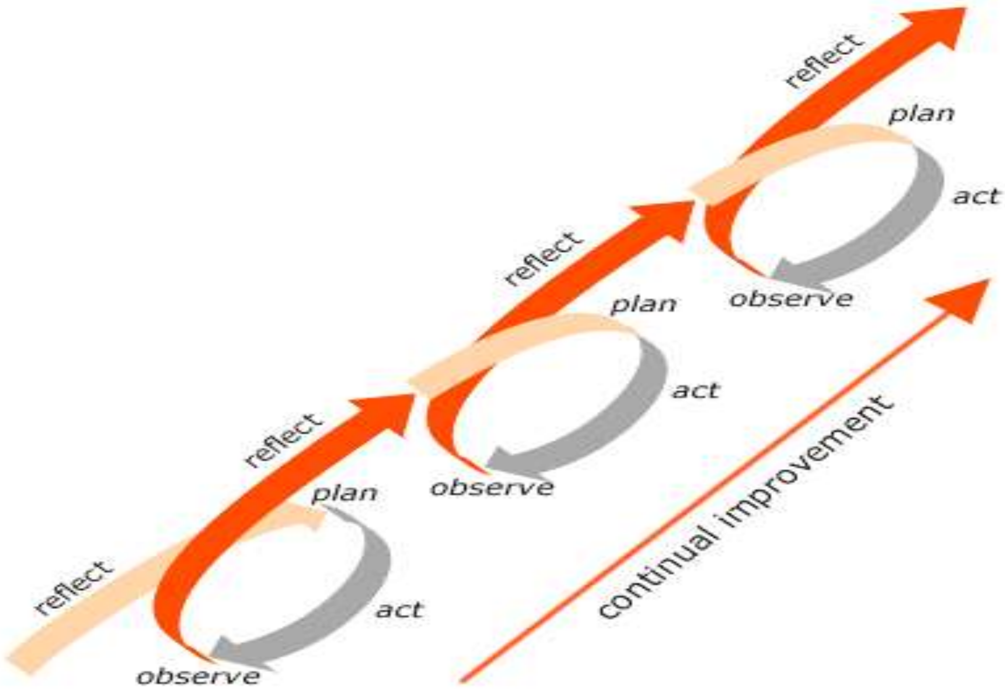

Fig. 3.1. Action Research Cycle (From: McNiff & Whitehead 2002). The action research cycle is generally given as a four-step cycle of *reflect → plan → act → observe.* That is: *reflecting* on one's practice and identifying a problem or concern, *planning* a strategy or intervention that may solve the problem, *acting* or carrying out the plan, and finally, *observing* the results or collecting the data.

Fig. 3.2: The four-step technique problem-solving flow chart.

Fig. 3.2: The four-step technique problem-solving flow chart. This describes the steps to follow to really understand the problem on hand.

Table 3.1. Grading criteria in assessing students.

Required Steps		Mark
Draw a Free Body Diagram		1
List all the Known's and the Unknowns		1
Select useful relations, formulas or equations		2
Plug in givens and solve for unknown		2
Answer checking	Numerically reasonable	2
	Dimensionally consistent	2

Table 3.1: Marking scheme used to assess students' work

Table 4.1: Frequencies and percentages of marks obtained by students for *question one* in the pre-intervention test.

Requirements		Marks obtained		
		0	**1**	**2**
List all the Known's and the Unknowns		0 (12) 75%	1 (4) 25%	-
Draw a Free Body Diagram		0 (11) 69%	1 (5) 31%	-
Select useful relations, formulas or equations		0 (8) 50%	-	2 (8) 50%
Plug in known values and solve for unknown value.		0 (9) 56%	-	2 (7) 44%
Answer checking	Numerically reasonable	0 (11) 69%	-	2 (5) 31%
	Dimensionally consistent	0 (13) 81%	-	2 (3) 19%

Table 4.1: Interpretation of students' performance in Question 1 on the pre-intervention test.

Table 4.2: Frequencies and percentages of marks obtained by students for *question two* in the pre-intervention test.

Requirements		Marks obtained		
		0	**1**	**2**
List all the Known's and the Unknowns		0 (13) 81%	1 (3) 19%	-
Draw a Free Body Diagram		0 (12) 75%	1 (4) 25%	-
Select useful relations, formulas or equations		0 (7) 44%	-	2 (9) 56%
Plug in known values and solve for unknown		0 (9) 56%	-	2 (7) 44%
Answer checking	Numerically reasonable	0 (10) 62.5%	-	2 (6) 37.5%
	Dimensionally consistent	0 (12) 75%	-	2 (4) 25%

Table 4.2: Interpretation of students' performance in Question 2 on the pre-intervention test.

Table 4.3: Frequencies and percentages of marks obtained by students for question three in the pre-intervention test.

Requirements		Marks obtained		
		0	**1**	**2**
List all the known's and the Unknowns		0 (13) 81%	1 (3) 19%	-
Draw a Free Body Diagram		0 (14) 87.5%	1(2) 12.5%	-
Select useful relations, formulas or equations		0 (2) 12.5%	-	2 (14) 87.5%
Plug in known values and solve for unknown		0 (7) 44%	-	2 (9) 56%
Answer checking	Numerically reasonable	0 (6) 37.5%	-	2 (10) 62.5%
	Dimensionally consistent	0 (7) 44%	-	2 (9) 56%

Table 4.3: Interpretation of students' performance in Question 3 on the pre-intervention test.

Table 4.4: Frequencies and percentages of marks obtained by students for *question one* in the post-intervention test.

Requirements	Marks obtained		
	0	**1**	**2**
List all the Known's and the Unknowns	0 (1) 6%	1(15) 94%	-

Draw a Free Body Diagram		0 (1) 6%	1(15) 94%	-
Select useful relations, formulas or equations		0 (2) 12.5%	-	2 (14) 87.5%
Plug in known values and solve for unknown		0 (3) 19%	-	2 (13) 81%
Answer checking	Numerically reasonable	0 (2) 12.5%	-	2 (14) 87.5%
	Dimensionally consistent	0 (2) 12.5%	-	2 (14) 87.5%

Table 4.4: Interpretation of students' performance in Question 1 on the post-intervention test.

Table 4.5: Frequencies and percentages of marks obtained by students for *question two* in the post-intervention test.

Requirements		Marks obtained		
		0	**1**	**2**
List all the Known's and the Unknowns		0 (0) 0%	1 (16) 100%	-
Draw a Free Body Diagram		0 (1) 6%	1(15) 94%	-
Select useful relations, formulas or equations		0 (2) 12.5%	-	2 (14) 87.5%
Plug in known values and solve for unknown		0 (2) 12.5%	-	2 (14) 87.5%
Answer checking	Numerically reasonable	0 (4) 25%	-	2 (12) 75%
	Dimensionally consistent	0 (2) 12.5%	-	2 (14) 87.5%

Table 4.5: Interpretation of students' performance in Question 2 on the post-intervention test.

Table 4.6: Frequencies and percentages of marks obtained by students for question three in the post-intervention test.

Requirements		Marks obtained		
		0	**1**	**2**
List all the Known's and the Unknowns		0 (1) 6%	1(15) 94%	-
Draw a Free Body Diagram		0 (1) 6%	1(15) 94%	-
Select useful relations, formulas or equations		0 (1) 6%	-	2 (15) 94 %
Plug in known values and solve for unknown		0 (2) 12.5%	-	2 (14) 87.5%
Answer checking	Numerically reasonable	0 (4) 25%	-	2 (12) 75%

	Dimensionally consistent	0 (1) 6%	-	2 (15) 94%

Table 4.6: Interpretation of students' performance in Question 3 on the post-intervention test.

Appendix A

Pre-intervention test items

1. A particle moving in a straight line with uniform deceleration has a velocity of $40ms^{-1}$ at a point P, $20ms^{-1}$ at a point Q and comes to rest at a point R where QR= 50m. Calculate the distance covered.
2. A stone is dropped down a well. If it takes 5s to reach the surface of the water, how deep is the well? (Take g= $10ms^{-2}$)
3. A particle is projected from the ground level with speed of $30m^{s-1}$ at an angle of 3^{0o} to the horizontal. Calculate the:
   - *i.* time of flight
   - *ii.* Range
   - *iii.* time taken to reach the maximum height
   - *iv.* greatest height [Take g=$10ms^{-2]}$

Appendix B

Post-intervention test items

1. A particle started from rest at a point R and moves with a uniform acceleration. It attained a velocity of $20ms^{-1}$ at point Q and $40ms^{-1}$ at point P. if the distance covered from R to Q is 50m; calculate the distance covered from Q to P.
2. A stone is thrown vertically upward with an initial velocity of $50ms^{-1}$, if it takes 5s to reach the maximum height, calculate the maximum height covered. (Take g= $10ms^{-2}$).
3. A particle is projected from the ground level with speed of $30ms^{-1}$ at an angle of 30^{o} to the horizontal. Calculate the:
   - *i.* time of flight
   - *ii.* range
   - *iii.* time taken to reach the maximum height
   - *iv.* greatest height [Take g=$10ms^{-2]}$