UNIVERSITY OF EDUCATION, WINNEBA

EFFECT OF TEACHING PROBLEM SOLVING HEURESTICS ON THE ACADEMIC PERFORMANCE OF SHS STUDENTS IN PHYSICS

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DECLARATION

Student's Declaration

I, ALFRED KWESI BEDU ARTHUR, declare that this Thesis, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere..

SIGNATURE: ……………………………

DATE: ……………………………………

Supervisor's Declaration

I, hereby declare that the preparation and presentation of the thesis was supervised in accordance with guidelines and supervision of dissertation laid down by the University of Education, Winneba.

NAME OF SUPERVISOR: DR. ISHMAEL KWESI ANDERSON

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DATE : ……………………………………………………

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DEDICATION

I dedicate this work to the Almighty God; I also dedicate it to my family; Mr. Armstrong Arthur –Baidoo, Mrs. Rebecca Arthur, Eunice Arthur, Evans Arthur, Evelyn Arthur, Alfred Arthur, Gilbert Arthur and Seth Arthur.

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ABSTRACT

The study was designed to improve students' academic achievements in physics. It was the belief of the author that if students' were allowed to develop higher cognitive processes through problem-solving instructional strategy using the five step problem solving heuristic proposed by Williams, Metcalfe, Trinklein and Lefler, called the Modern Physics Problem Solving Rule, it might improve positively their academic performance and for that matter increase their interest in physics. Therefore, effect of incorporating problem solving heuristics in teaching on the academic performance and interest of students toward physics was investigated. Kwanyako Senior High School science students constituted the population of this study. The form two (2) science students numbering twenty three were selected as the sample for the study. The main instruments used to collect data were test items and a checklist. The test items consisted of pre-intervention test and post-intervention test items. A grading criterion that emphasizes certain problem solving skills was developed to monitor students' learning progress. The developed checklist had eight items which captured certain behaviours that depict an interest or loss of interest in a subject. Duration of six weeks' intervention plan with the class using an innovative method of teaching problem solving strategy was employed. The data collected from pre-intervention test and post-intervention test were analysed using frequency counts and percentages. A paired sample t-test with the aid of the SPSS version 20.0 showed that there was a significant difference in the pre-intervention test and post-intervention test scores. The post-intervention test analysis manifested that there had been an improvement in the way students solved physics problems. With regards to the interest towards physics, the same trend was observed after the analysis. The students' interest towards the study of physics was higher after the implementation of the intervention. Students, who did not enjoy physics, now asked for more physics problems at the later part of the study. The study recommends the use of proactive ways of presenting subject material so as to guide students' learning efforts. Once the problem- solving abilities of students are animated, improved performance and interest towards physics will automatically follow.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter deals with the background to the study, the statement of the problem, purpose of the study, objectives of the study, research questions, significance of the study, delimitation and limitations of the study . It also discusses the meaning of problem solving as used in this study.

1.1 Background to the study

Improving students' understanding of physics concepts and enhancing their problem solving skills might be considered the two main objectives in many physics classrooms. Problem solving can be an important component in many introductory and advanced level physics courses. Many instructors make use of the problem solving activities to clarify and emphasize the physics concepts and principles (Shih-Yin, 2012). Recently, physics educators have begun to explore how to overcome the difficulties students encounter in Physics (Thornton & Sokoloff, 1990). The ability to solve complex, real-world problems and the ability to design and conduct systematic investigations are among the most important skills people use in the workplace, according to several recent studies (Thornton & Sokoloff, 1990).

Most of the early research in physics education was focused on students' conceptual understanding in physics, especially in introductory mechanics (May, 2002). According to May (2002), a large body of literature relating to the problem solving process and the effective teaching of problem solving has been built. When problems are presented to students, certain skills may be needed in order to solve the problem efficiently. The ability to organize the problem to bring out items needed to execute the problem, use appropriate relations and synthesize the items are all needed skills to help in solving the problem efficiently. This implies that students studying physics are expected to learn both the descriptive or conceptual side of physics and the logical reasoning aspect as well. It is evident that in order to become a good problem solver, a student must possess the necessary domain knowledge, as well as an understanding of general problem solving process and heuristics (Maloney, 1994). Problem solving has been suggested as the process of moving towards a goal when the path to the goal is uncertain (Martinez, 1998). Good problem solvers (expects) attempting to attain the unknown, then they might have had a set of both general and specific heuristic (strategies) at their disposal. Even in teacher education, research has generated social problem-solving models (Cummings & Curtis, 1992) intended to describe the total process of social problem solving in student teachers. Not surprisingly, the elements described in these models are remarkably similar to those generated in art education (Foshay, 1998; Sapp, 1995), and various other fields such as literacy and aesthetic education (Handerhan, 1993), clinical diagnosis (Kagan, 1988) and mathematics education (Schoenfeld, 1985).

It appears that conceptual reasoning is severely underemphasized in many traditional physics courses since most traditional courses seem to lack in an explicit teaching of students in problem solving strategies and only emphasize plug and chug approach. Students in this situation are likely to solve physics problems by applying concepts without thinking if it is applicable or not. The student's knowledge of physics may be traditionally checked via problem-solving exams. Physics instruction is about having students solve problems. According to

Schultz and Lochhead (1991), the fact is that the solving of physics problems is the preferred, almost universal, means of demonstrating mastery of physics. Therefore investigation of students reasoning through problem solving is very important to help students learn better. Being familiar with students' thinking process and knowledge state can help instructors use appropriate research-based strategies to improve student learning.

In most African countries, a study has highlighted an alarming decline in young people's interests for key science studies (Omosewo, 1999). Some other related studies have revealed that the performance of students in Physics has generally and consistently been poor over many years, most especially those concerning females (Wambugu & Changeiywo, 2008; Oladajo, Olosunde, Ojebisi& Isola, 2011). For example, Donnellan (2003), Anamuah- Mensah (2004) and Buabeng (2012) all found out in their studies that there were low interest and poor performance of students in the study of physics, especially females. One major cause or attribute that surfaced in all those studies was how physics content knowledge was taught and learned at all the academic levels. There is therefore the need for stakeholders in education to find new and better ways of approaching the teaching and learning of physics.

1.1.1 Problem solving:

The term problem-solving is used in many disciplines, sometimes with different perspectives, and often with different terminologies. For instance, it is a mental process in psychology and a computerized process in computer science. Problems can also be classified into two different types (ill-defined and well-defined) from which appropriate solutions are to be made (Schacter &Addis, 2009). Ill-defined problems are those that do not have clear goals, solution paths, or expected solution. Well-defined problems have specific goals, clearly defined solution paths, and clear expected solutions. These problems also allow for more initial planning than ill-defined problems (Schacter &Addis, 2009). Being able to solve problems sometimes involves dealing with pragmatics (logic) and semantics (interpretation of the problem). The ability to understand what the goal of the problem is and what rules could be applied represents the key to solving the problem. Sometimes the problem requires some abstract thinking and coming up with a creative solution. Problem solving as used in this research refers to the ability to identify a problem and develop correct systematic schemes or steps to obtain a solution to that problem. Whereas each of these steps is considered as separate skill, each step is categorized into sub skills. These skills can be considered as the analytical parts (heuristics) of the problem solving process which requires defining, investigating, reviewing and processing of the information regarding the problem. Somewhat synonymous term is “strategies”. A problem-solving strategy is a technique that may not guarantee solution, but serves as a guide in the problem solving process. The problem may take different forms. It can be in a word or mathematical format presented to the students or real world problems we encounter in our daily life activities.

1.2 Statement of the problem

One of the major problems in learning Physics is the difficulty encountered by students when solving Physics problems. This problem persists because students do not have the requisite skills and strategies in solving problems. The problem also persists because students cannot change a problem presented to them in words into variables. Therefore students are to be helped out to overcome these difficulties at physics learning.

According to McDermott and Shaffer (1992), the goal of an introductory physics course is to enable students to develop complex reasoning and problem solving skills and be able to use these skills in a unified manner to explain and predict diverse phenomena in everyday experience. However, research in science education shows that students do not acquire these skills from a traditional course (McDermott & Shaffer, 1992). In order to learn physics effectively, it is essential to unpack the meaning of the abstract principles, and understand their applications in diverse situations (Hammer, 2000; Redish, Scherr, & Tuminaro, 2006). Experienced teachers are aware that many students complete science courses without learning the basic concepts and skills that teachers intend for them to learn. According to Heuvelen (1991), many students leave the introductory physics course without the level of understanding of physics concepts and problem-solving skills valued by the instructors. This is because students often solve problems based on the recognition of surface features and rote memorization, rather than the analytical process that the instructors would like to have students implement (Chi, Feltovich, & Glaser, 1981; Maloney, 1994; Mazur, 1997; McDermott, 1993).

The low performance of Ghanaian students in West African Senior Secondary School Certificate Examination (WASSCE) in Physics has been a major worry for many stakeholders in the educational enterprise for recent past years. The chief Examiner’s report for the May/June 2012 WASSCE indicates that the performance of students in Physics is below average, and this poor performance of candidates, he attributed to poor reasoning and poor problem solving skills on the part of students and also ineffective teaching strategies on the part of teachers (Chief Examiner, 2012). When expects solve a physics problem, they link fundamental physics concept to their knowledge of a physical situation. This connections or linkage our students are unable to do, hence the need to find ways to curtail the problem.

So the difficulty encountered by science students in solving physics problems as a result of poor problem solving skills, poor reasoning (thus inability to link fundamental physics concepts to their knowledge of a physical situation) and the low performance in physics are some of the problems that prompted the researcher to adopt the incorporation of problem solving heuristics in his teachings to help improve students' performance in Physics.

1.3 Purpose of the study

The main purpose of the study was to evaluate effect of incorporating problem solving heuristics in teaching on the academic performance of science students in Physics in the Agona East District of Ghana. Therefore, the study's purpose is focused to reveal how students approach and solve physics problems given to them, highlight some of the causes of students' inabilities to solve physics problems, identify the effect of guiding students in solving Physics related problems, how students can be helped to improve their academic performance in physics when taught better approaches to solving problems and finally, resist the false impressions that physics is difficult as we hear among science students.

1.4 Objectives of the Study

The study was designed to:

1. Determine the academic performance of form two science students in Physics before the incorporation of problem solving heuristics in teaching of Physics.
2. Determine the academic performance of form two science students in Physics after the incorporation of problem solving heuristics in teaching of Physics.
3. Determine the effect of incorporating problem solving heuristics in the teaching of Physics on the interest of students towards the study of Physics.

1.5 Research Questions

The following research questions guided the study:

1. What is the academic performance of Kwanyako science students in physics before the incorporation of problem solving heuristic in teaching of physics?
2. To what extent will the incorporation of problem solving heuristic in the teaching of physics improve the academic performance of Kwanyako science students?
3. What influence will incorporation of problem solving heuristic in teaching have on the interest of Kwanyako science students towards the study of Physics?

1.6 Significance of the study

This study would help clarify the misconception students have in the study of Physics in general. The findings and recommendation of this study would be of much benefit to Kwanyako Senior High School science students which will go a long way to improve their academic performance both in internal and external examinations. Again the educational implication is that, as the use of problem solving strategy in teaching could show positive results among students in the school, they have the potentials of replacing the traditional lecture method of instruction, as the benefits of these instructional approaches are becoming motivating factors for improving physics teaching and learning.

Kwanyako Physics teachers on the other hand will gain the ability to identify students' problems as well as difficulties they face and then find remedies towards rectifying them. Again findings from this work could help Kwanyako physics teachers to adopt the best instructional teaching strategies in helping students to understand the concepts of Physics. The study would make stakeholders in the educational sector to be conscious of the need and usefulness in adopting different instructional teaching strategies in teaching and learning in Ghanaian schools.

Finally, this study could add to existing literature on methodologies of teaching Physics as well as serve as a source of information for further research work. The study will also go a long way to help curriculum developers to strategize the curriculum such that different strategies of teaching will be included in it.

1.7 Delimitation

Though the Central Region of Ghana has a large number of senior high schools, this study's interest was on only one senior high school in the Central Region because of the researcher's involvement with the school as a Physics teacher.

Again, the study could not include more senior high schools due to lack of funds, proximity of the researcher and also accessibility to the population. Also, due to the limited duration of the program, only the science class from Kwanyako Senior High School was used instead of selecting the Science Students in the Agona East District. Using only one School saves time and cuts down the population of the students.

1.8 Limitation of the study

Ideally, a large number of Senior High Schools across the nation should have been the target for the study. However, only one school was selected and even that only the form two science students were used due to two major reasons:

- The form three students' preparation towards the final exams (WASSCE) did not permit for their inclusion in the study.
- The form one students were not introduced to much physics concept as at the time the study was being carried out.

These will make generalization of the research to be limited to a small scope of students within the targeted population.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

The chapter covers a review of literature related to this study. The review of this study will focus primarily on research done on physics problem solving. However the chapter also highlights the performance of students in physics, problem solving in science in general, what entails in the teaching of physics. The chapter also discusses expect-novice difference when it comes to problem solving; learning from examples as a way of mastering problem solving, expect problem solving approaches, and problem solving heuristics. The chapter ends by explaining the importance of problem solving to students in the classroom and their immediate environment outside the classroom, the theoretical framework underpinning this study and the educational implications of the Bandura's Social Learning Theory (SLT).

2.1 Academic Performance of Students in Physics

Physics is very interesting and one of the best sciences in the world. There is no gain saying about the fact that physics occupies a very sensitive position in physical science and related discipline. This informs several efforts geared toward studying physics at higher secondary level of education. Hence, it is one of the science subjects one must pass so as to qualify to offer some science courses at tertiary level of education. It is however, very disheartening and heartbreaking that despite the key role and much emphasis being laid on physics, students at higher secondary school level of education are still performing woefully in this subject. This has become an issue of great concern to stake holders in education, most especially those in the field of science. This has been attributed to myriad of factors such as poor parenting, poor attitude of students towards their studies (Federal Republic of Nigeria, 1981). Bassey (2005) opined that several problems are associated with conventional method of teaching. This, indirectly result to poor performance of students. Bassey (2005) attributed this syndrome in educational sector to lack of perceived competence among the learners. However Adegbite (2000) and Olaleye (1985) views on the causes of poor performance in physics differs. They posited very strongly that wrong location of market place, highway, airport, and industrial areas constitute an academic unfriendly environment for learners. Agusibo (2008) asserted that, many schools lack the necessary facilities for teaching generally. She however, opines that theoretical aspect of teaching alone will not make learners know the rudimentary fact of most science subjects' biology inclusive. She therefore made a clarion call to all the key players, international organization like United State Agency for International Development, World Health Organization, United Nation Education Scientific and Cultural Organization, United Nation International Children Education Fund, World Bank and non-governmental organization to render in valuable services by rescuing most schools by making available supportive services for teaching of physics and other science subjects that, theory alone will do more harm than good to effective learning in physics. In trying to ascertain the academic performance of students in physics Mohd, Tabasum and Ruhee (2013) found out that the teacher as a person is not the sole determinant of students' academic outcome because other factors such as socio-economic status, parental education, school environment, and related factors have significant effects in the academic performance of higher secondary school students.

2.2 Problem Solving in Science

The word 'problem' was described by Hayes (1989) as the gap between where you are now and where you want to be, and you do not know how to find a way to cross that gap. According to Baron (1991), problem solving involves a process which is identified as characteristic of reasoning such as assumption, inferences, predictions, arguments and the selection of examples and counter- examples to validate or refute statements. Problem solving usually consist of strategies or techniques adopted to suit its intended purpose. The strategies may serve as a guide in addressing the challenges or obtaining solutions to problems which in effect will improve understanding as well as performance (Stewart, 1988). Martinez (1998) defined problem solving as "the process of moving towards a goal when the path to the goal is uncertain" (p.605). According to Perkins, Faraday and Bushey (1991), problem solving lies on a situational modeling and this is clearly provided to the student who ought to understand it. Good and Smith (1987) provided a summary on problem solving in science education. According to them, current research on problem solving in science education involves information processing theory. The idea is that solving a problem requires two processes which are retrieval from memory of the pertinent information and proper application of the information to the problem. Stewart (1988) discusses ways in which different problem types may contribute differentially to learning outcomes. Stewart further contended that there are two main types of thinking involved in problem solving. The types include reasoning from cause to effect and reasoning from effect to cause. 'Cause to effect' problems do not provide students with insight into nature of science. However, effect to cause problems can be developed if computer-generated information is provided (Stewart, 1988). Earlier work on the importance and necessity of a problem solving strategy can be found in the work of the great mathematician George Polya (Polya, 1957) who placed emphasis on the relevance of the systematicity of a problem-solving strategy for productive thinking, discovery and invention. Some of his views, either provocative or encouraging, about teaching and learning can be found in some Physics Education Research publications, like for instance his statements that teaching is not a science (Hammer, 1996) and that teaching is an art and his views on the aim of teaching and on the importance of problem solving skills (Heller, Keith, & Anderson, 1992).

2.3 Teaching Physics

According to Bruce and Weil (1986), teaching is the creation of environment in which student's cognitive structures emerge and change. The goal is to provide learning experience that gives the students practice with operations. To achieve the aim of science (Physics) the subject should be taught with varying teaching methods to suit the learning content. Physics is a discipline, which is difficult to be understood or studied when its teaching is devoid of any practical activity. Schoenfeld (1985) in review of mathematics education literature, pointed out that the research result in the early 1980's demonstrated that for effective problem solving, it is not just what you know, its 'how' 'when' and 'whether' you use it. In addition to knowing 'what' and 'how', the problem solver must also develop the knowledge about the 'when' and 'why' of using the strategies appropriately (Paris & Meyers, 1978).

2.4 Problem-solving in Physics

Problem-solving is an integral part of most (if not all) introductory physics courses. Physics textbook chapters end with many problems for the students to solve, while the chapters themselves are full of worked examples. The traditional lectures are full of solved problems, a fact not missed by one of Tobias's expert auditors, "the class consisted basically of problem solving and not of any interesting or inspiring exchange of ideas" (Tobias, 1990, p.20). The student's knowledge of physics is traditionally checked via problem-solving exams. Physics instruction is about having students solve problems. According to Schultz and Lockhead (1991), solving of physics problems is the preferred, almost universal, means of demonstrating mastery of physics. Clearly an emphasis on problem solving is throughout a traditional introductory physics course and a means for course evaluation.

2.5 Experts-Novice Difference in Problem Solving

Research on expert-novice difference indicates that when solving problems, experts tend to focus on deep features while novices are more likely to be distracted by the surface features (Chi, Feltovich, & Glaser, 1981; Hardiman, Dufresne, & Mestre, 1989). Prior studies on the categorization of introductory mechanics problems indicates that while novices may group two problems together because both of them involve an inclined plane, experts are likely to notice that one of the problems involves the principle of conservation of energy but the other problem involves a different principle (such as Newton's 2nd Law) so that they place these problems in two different categories (Chi, Feltovich, & Glaser, 1981). The findings suggest that experts usually group problems based upon the physics principles but novices usually group problems based on the surface features. The different ways experts and novices categorize problems reflect the different ways knowledge is organized in their minds (Johnson-Laird, 1972; Bobrow & Norman, 1975; Chi, Feltovich, & Glaser, 1981; Larkin, 1981; Reif & Heller, 1982; Schoenfeld & Herrmann, 1982; Eylon & Reif, 1984; Cheng & Holyoak, 1985; Marshall, 1995; Johnson & Mervis, 1997; Dufresne, Mestre, Thaden-Koch, Gerace, & Leonard, 2005). Experts have a pyramid-like knowledge hierarchy in which the most fundamental principles are placed at the top, followed by layers of subsidiary details. This organized knowledge structure allows the experts to focus on the fundamental physics principles when solving problems and it also allows them to transfer better between various contexts (Chi, Feltovich, & Glaser, 1981; Novick, 1988; Bassok & Holyoak, 1989; Brown, 1989; Detterman & Sternberg, 1993; Dufresne, Mestre, Thaden-Koch, Gerace, & Leonard, 2005; Ozimek, Engelhardt, Bennett & Rebello, 2004).

2.6 Learning from Examples

Research suggests that at the initial stages of skill acquisition, learning can be more effective through the studying of worked-out examples than the actual practice of problem solving (Ward & Sweller, 1990). Because the cognitive overload is less when studying worked examples than when actually solving problems, and more spaces in short term memory can become available for students to extract useful strategies and to develop knowledge schemas (Paas, 1992; Sweller, Merrienboer & Paas, 1998; Atkinson, Derry, Renkl &Wortham, 2000). Research also suggests that there is a difference between how good students and poor students study worked-out examples (Chi, Bassok, Lewis, Reimann & Glaser, 1989; Ferguson, Hessler & Jong, 1990). Good students typically engage in deeper processing than the poor students (Chi, Bassok, Lewis, Reimann & Glaser, 1989; Ferguson, Hessler & Jong, 1990). Presenting students with examples to demonstrate the meaning and application of a physics concept is a very common pedagogical tool in physics. Research on learning from worked-out examples such as those in a textbook (Atkinson, Derry, Renkl &Wortham, 2000; Chi, 2000; Yerushalmi, Mason, Cohen & Singh, 2008) has shown that students who self-explain the underlying reasoning in the example extensively learn more than those who don't self-explain even if the self-explanations given by the students are sometimes fragmented or incorrect. It is suggested that the largest learning gain can be achieved if students are actively engaged in the process of sense making while learning from examples (Chi, Bassok, Lewis, Reimann & Glaser, 1989; Aleven, Koedinger &Cross 1999; Chi 2000; Yerushalmi, Mason, Cohen & Singh, 2008)

2.7 Expert Problem Solving Approaches

People who have developed expertise in particular areas are by definition, able to think effectively about problems in those areas. Understanding expertise is important because it provides insights into the nature of thinking and problem solving. Research shows that it is not simply general abilities, such as memory or intelligence, nor the use of general strategies that differentiate experts from novices. Instead, experts have acquired extensive knowledge that affects what they notice and how they organize, represent, and interpret information in their environment. This, in turn, affects their abilities to remember, reason, and solve problems. Some of the several key principles of expects' knowledge and their potential implications for learning and instruction are outlined below as expects

- notice features and meaningful patterns of information that are not noticed by novices;

- have acquired a great deal of content knowledge that is organized in ways that reflect a deep understanding of their subject matter;
- have knowledge that cannot be reduced to sets of isolated facts or propositions but, instead, reflects contexts of applicability implying that the knowledge is "conditionalized" on a set of circumstances;
- are able to flexibly retrieve important aspects of their knowledge with little attentional effort and
- have varying levels of flexibility in their approach to new situations.

2.7.1 Meaningful patterns of information

The idea that experts recognize features and patterns that are not noticed by novices is potentially important for improving instruction. When viewing instructional texts, slides, and videotapes, for example, the information noticed by novices can be quite different from what is noticed by experts (Sabers, Cushing & Berline, 1991; Bransford, Hasselbring, Barron, Kulweicz, Littlefield & Goin, 1988). One dimension of acquiring greater competence appears to be the increased ability to segment the perceptual field (learning how to see). Research on expertise suggests the importance of providing students with learning experiences that specifically enhance their abilities to recognize meaningful patterns of information (Simon, 1980; Bransford, Franks, Vye & Sherwood, 1989). An emphasis on the patterns perceived by experts suggests that pattern recognition is one of the important strategies for helping students develop confidence and competence. These patterns provide triggering conditions for accessing knowledge that is relevant to a task.

2.7.2 Organization of knowledge

Their knowledge is not simply a list of facts and formulas that are relevant to their domain, but instead, their knowledge is organized around core concepts or "big ideas" that guide their thinking about their domains. In an example from physics, experts and competent beginners (college students) were asked to describe verbally the approach they would use to solve physics problems. Experts usually mentioned the major principle(s) or law(s) that were applicable to the problem, together with a rationale for why those laws applied to the problem and how one could apply them (Chi, Feltovich & Glaser, 1981). In contrast, competent beginners rarely referred to major principles and laws in physics, but instead, they typically described which equations they would use and how those equations would be manipulated (Larkin, 1981; 1983).

Experts' thinking seems to be organized around big ideas in physics, such as Newton's second law and how it would apply, while novices tend to perceive problem solving in physics as memorizing, recalling, and manipulating equations to get answers. Research on expert problem solving strategies indicates that experts typically start with a re-description of the problem information and then use the relevant information to plan the solution before executing it (Larkin, 1979; Larkin, McDermott, Simon & Simon, 1980; Larkin 1981; Chi, Glaser & Rees, 1982; Eylon & Reif, 1984; Bagno & Eylon, 1997). When solving problems, experts in physics often pause to draw a simple qualitative diagram. They do not simply attempt to plug numbers into a formula. The diagram is often elaborated as the expert seeks to find a workable solution path (Larkin, McDermott, Simon & Simon, 1980; Larkin & Simon, 1987; Simon & Simon, 1978).

2.7.3 Context and access to knowledge

Experts have a vast repertoire of knowledge that is relevant to their domain or discipline, but only a subset of that knowledge is relevant to any particular problem. Experts do not have to search through everything they know in order to find what is relevant otherwise that approach would overwhelm their working memory (Miller, 1956). Experts have not only acquired knowledge, but are also good at retrieving the knowledge that is relevant to a particular task. In the language of cognitive scientists, experts' knowledge is "conditionalized" it includes a specification of the contexts in which it is useful (Simon, 1980; Glaser, 1992). The issue of retrieving relevant information provides clues about the nature of usable knowledge. Knowledge must be "conditionalized" in order to be retrieved when it is needed; otherwise, it remains inert (Whitehead, 1929). The concept of conditionalized knowledge has implications for the design of curriculum, instruction delivery, and assessment practice that promote effective learning. One way to help students learn about conditions of applicability is to assign word problems that require students to use appropriate concepts and formulas (Lesgold, 1984, 1988; Simon, 1980). If well designed, these problems can help students learn when, where, and why to use the knowledge they are learning.

2.7.4 Fluent retrieval

People's abilities to retrieve relevant knowledge can vary from being "effortful" to "relatively effortless" (fluent) to "automatic" (Schneider & Shiffrin, 1977). Automatic and fluent retrieval are important characteristics of expertise. An important aspect of learning is to become fluent at recognizing problem types in particular domains such as problems involving Newton's second law or concepts of rate and functions so that appropriate solutions can be easily retrieved from memory. The use of instructional procedure that speed pattern recognition is promising in this regard (Simon, 1980).

2.7.5 Adaptive expertise

The concept of adaptive expertise provides an important model of successful learning. Adaptive experts are able to approach new situations flexibly and to learn throughout their lifetimes (Hatano & Inagaki, 1986). They not only use what they have learned, they are metacognitive and continually question their current levels of expertise and attempt to move beyond them. They do not simply attempt to do the same things more efficiently; they attempt to do things better (Hatano & Inagaki, 1986). A major challenge for theories of learning is to understand how particular kinds of learning experiences develop adaptive expertise.

The studies on how experts approach problem solving suggest another perspective to help enhance students' problem solving performance by adopting a systematic problem solving approach (Polya, 1945; Heuvelen, 1991; Reif, 1995; Heller & Heller, 2000). A recent study on physics experts' problem solving approaches when their intuition fails also observes that expert problem solvers typically adopt a systematic problem-solving heuristic (such as first visualizing the problem, considering different conservation principles, and examining limiting cases) when they are presented with a novel situation (Singh, 2002). Research indicates that by explicitly modeling and encouraging students to follow a set of problem solving procedures, students are likely to achieve a better performance (van Weeren, de Mul, Peters, Kramers-Pals & Roossink, 1982; Heller & Reif, 1984; Wright & Williams, 1986; Huffman, 1997).

2.8 Problem solving heuristic

A heuristic is a rule of thumb, a strategy that is both powerful and general, but not absolutely guaranteed to work (Kuo, 2004). In problem solving, heuristics play a major role in the solution process. Heuristics exist because more often than not, they aid in finding an easy path to the answer in complex problems (Renkl, Hilbert, & Schworm, 2008). Simon (1980) likened problem solving to working through a maze. In negotiating a maze, one works towards the goal step by step, making some false moves, and gradually moves closer to the intended end point. The rule of choosing a path that seems to result in some progress toward the goal may have guided the choices that one makes in negotiating the maze. Such a rule, called "means-ends analysis", is an example of a heuristic (Kuo, 2004). Means- ends analysis suggests the formation of sub-goals to reduce the discrepancy between the current state and the ultimate goal state. This heuristic helps the problem solver move incrementally towards the ultimate goal, but is not a process of trial and error because the steps taken are not random. The series of steps are applied tactically for the purpose of moving closer to the goal.

Under some assumptions, the problem solver should always choose the action, which leads to the state that minimizes problem. However, if the expanse from the start is not the minimal space, and if the estimated distance to the goal is not accurate, the problem solver may end up searching a large proportion of the problem space. This is not very effective or practical, especially if the problem space is large. Having too many solution paths make it hard to find the answer

(Patra, Goswami, & Goswami, 2009). Rules of thumb (often informally called heuristics) limit the search space, thus making the solution more likely (Vrakas & Vlahavas, 2005). Unless the problem is extremely familiar to the problem solver, at which point he/she may store the state space in long-term memory, he/she cannot search large parts of the problem space due to the limitations of short-term memory. In fact, such a search is often not needed. Many problems can be solved quite well by building the solution path, rather than by exploring a large number of alternatives (Pizlo & Li, 2005). When a problem is solved by building a solution path, the solution may not be optimal (in terms of the path length), but it is likely to be economic in terms of the time spent solving the problem. Practically, what matters in everyday life is to solve problems and to solve them quickly

2.9 Problem solving heuristic models

The physics textbook contains many solved "sample problems". The solutions presented there are analogous to a completed jigsaw puzzle, with every piece in its proper position (Styer, 2002). No one solves a physics problem by simply writing down the correct equations and the correct reasoning with the correct connections the first time through, just as no one builds a jigsaw puzzle by putting every piece in its correct position the first time through. To Styer, the "solved problems" in the text book are extraordinarily valuable and they deserve careful study, but they represent the end product of a problem solving session and they rarely show the process involved in reaching that end product. This study aims to expose the processes involved. Some research endeavors in physics have come out with various heuristics of tackling and solving problems in physics. Some of the preferred heuristics are the

- Polya's problem solving activity;
- model of teaching methods;
- teaching science through discovery;
- working backward;
- modern physics problem solving rules;
- physics problem solving strategy;
- understanding basic mechanics method;
- competent problem solving method and
- successive approximation method

In the Polya's problem solving activity, students can learn to become better problem solvers. Polya (1957) in his book "How to Solve It", presented four phases or areas for problem-solving, which have become the framework often recommended for teaching and assessing problem-solving skills. The four steps are the ability to understanding the problem, devise a plan to solve the problem, implement the plan and reflect on the problem. Surprisingly, these steps encompass the mental processes and unconscious questions experts explore as they themselves approach problem solving. These four steps also form the basis for some computational models devised to model and explore scientific discovery processes (Polya, 1973). Nevertheless, even though the aforementioned four steps seem very simple, their generality makes it hard for novices to follow them. Some problem-solving processes can be represented on chart and these charts illustrate several strategies to be used to facilitate work with problem-solving (Waddling & Robin, 1988).

As with the model of teaching methods, Bruce and Weil (1986) categorized classroom model for problem solving into six phases. Three of the phases that are vital to problem solving in physics are considered in this research and are described below. The first phase is establishing a climate of environment. In this phase, the teacher encourages everyone to participate and speak for himself or herself, share opinions without blame or evaluation. The second phase is exposing the problem for discussion. Here, the teacher or students bring up issue or problem. The teacher now gives examples, describes problem fully and identify consequences. The third phase is identifying alternative causes of the action. The teacher discusses specific alternatives to help solve the problem. Students agree on which ones to follow (Bruce, & Weil, 1986).

Teaching science through discovery as suggested by Arthur and Robert (1989) was that problems vary in nature and so different approaches may be needed in their solutions. However, guiding students in problem solving will include the following chain as

Planning → Obtaining data → Organizing data → Analysis of data → Synthesizing or Generalizing from data → Decision making.

For “working backward” as a problem solving heuristic model, the problem solver first considers 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 backwards and eventually reaches the initial conditions of the problem (Simon, Langley & Bradshaw, 1980; Kuo, 2004).

In the modern physics problem solving rules, Williams, Metcalfe, Trinklein and lefler (1986) were of the opinion that methods used to solve physics problems consist of a number of logical steps. These steps as discussed below expect the problem solver to write down the symbols for the physical quantities called out for in the problem, together with their appropriate units, then followed by writing the equation relating the known quantities of the problem. This is called the basic equation. It is also helpful to draw a sketch of the problem and to label it with given data. The next step is to solve the basic equation for unknown quantities in the problem, expressing these quantities in terms of those given in the problem. This is called the working equation. After solving the working equation, the given data is substituted into the working equation. This is done by making sure that the correct units of the various quantities are used. The mathematical operations with the units along are performed making sure the answer is in the units called out for in the problem. The process is called dimensional analysis. Estimation of the order of magnitude of the answer is now done. The next is to perform the indicated mathematical operations with the number. Finally, the entire solution is reviewed and compared with the estimated answer (Williams, Metcalfe, Trinklein & lefler, 1986).

Another heuristic, the physics problem solving strategy, involves two factors that can help make one a better Physics problem solver according to Hollabaugh (2010). First of all, one must know and understand the principles of physics. Secondly, the person must have a strategy for applying these principles to new situations in which physics can be helpful. Many students say, “I understand the material, I just cannot solve the problem”. Hollabaugh further indicated that physics problem solving can be learned just like you learned how to drive a car, play a musical instrument, or ride a bicycle. The best aid is to have a general approach to follow whenever you encounter any problem. Different tools or tactics may be used for different problems, but the overall heuristic remains the same. As with so many other learning activities, it is useful to break a problem solving heuristic into major and minor steps (Hollabaugh, 2010). The general strategy proposed by Hollabaugh for solving all problems either physics or any other problem has five phases of focusing on the problem, describing the physics of the problem and planning a solution for solving the problem. The rest of the phases include executing the plan to solve the problem and finally evaluating the solution. Each of the phases has a detailed description and sub steps of how to go about when solving a physics problem.

Understanding basic mechanics method which was developed by Reif (1995) is structured into three basic steps. These are to analyze the problem, construct solution and check the solution. The first and third are broken into a list of questions that the student needs to ask about the problem and factors that should be taken into account. The second step is concerned with finding appropriate sub problem that resemble the exercise the students are already familiar with or can easily figure out how to work. In constructing the solution, the student first determines what need to be done by asking these self-questions; is there missing information? Are there unknown that might be removed by proper combination of these relations? Once that has been determined the student is helped along the path to accomplishing the sub-goals (Reif, 1995).

The competent problem solving method is among a set of instructional strategies designed by researchers to help novices become more expert-like in their approaches to solving problems. Heller, Keith, and Anderson (1992) introduced a five-step problem solving strategy, which they expect the student or problem solver to visualize the problem as the first step, then describe the problem in science terms. Planning a solution, executing the plan and checking and evaluating are the last three steps.

Successive Approximation method is another heuristic applied in solving problems. The initial goal of successive approximation is to produce a rough draft or an outline of ideas. Over time, the draft is organized and refined into something better, with new ideas added and old ideas removed (Kuo, 2004). Eventually, a polished form emerges that finally approximates the effect that the problem solver intended according to Kuo, (2004).

These are the few problem-solving heuristics that can be employed when solving problems in physics. However, many other strategies could be added to help make students good problem solvers. The process of problem solving should be seen as a dynamic, non-linear and flexible approach (Dishion & Kavanagh, 2003). Learning these and other problem-solving strategies will enable students to deal more effectively and successfully with most types of mathematical and scientific problems. These problem-solving processes could be very useful in mathematics, science, social sciences and other subjects. Students should be encouraged to develop and discover their own problem-solving strategies and become adept at using them for problem-solving. This will help them to develop in their confidence in tackling problem-solving tasks in any situation, and enhance their reasoning skills. As soon as the students develop and refine their own repertoire of problem-solving strategies, teachers can highlight or concentrate on a particular strategy, and discuss aspects and applications of the strategy (Florida Department of Education, 2010).

2.10 Significance of problem solving

By improving the problem solving skills of students, it may be easier to spot conceptual difficulties that the students have. As cognitive science researcher Greeno said, "The process used to generate concept and procedures in novel situations probably correspond to general problem solving skills" (Greeno, 1978, p 266).

It has been noticed that problem solving skills are often limiting factors to students' academic performance. They may understand it but are blocked by inability to do the problem itself. According to Bagdanov and Kjurshunov (1998), as far as education and teaching are concerned, problem solving is one of the best ways to involve students in the thinking operation of analysis, synthesis and evaluation which are considered as high-order cognitive skills.

Drilling students on exercise based on materials presented in lecture was the standard practice of teaching physics many years ago. The feeling was that once the students mastered the techniques, understanding of concept would follow (Bagdanov & Kjurshunov, 1998). It was later realized that improving the problem solving skills of the students is the best way to spot conceptual difficulties (Greeno, 1978).

The National Science Teachers Association (NSTA) in the 1980 position statement advocated that science teachers help students learn and think critically and logically, specifying that high school laboratory and field activities should emphasize not only the acquisition of knowledge but also problem solving and decision making (NSTA,1980). According to the Ghana senior high school physics syllabus (2007), teachers are entreated to take students through problem solving. When this is done, students would develop quality skills in problem solving which will enable them to solve problems they encounter in the class and their immediate environment faster and with a high degree of accuracy.

2.11 Theoretical Framework

The study is influenced by the behaviorist theory specifically Bandura's Social Cognitive Learning theory. The theory, viewed learning as occurring within a social context and regards humans as self-organizing, proactive, self-reflecting and self-regulating. Bandura agrees with the behaviorist learning theory of classical conditioning and operant conditioning by incorporating two important ideas that, mediating processes occur between stimuli and responses, and that behavior is learned from the environment through the process of observational learning (Bandura, 1977).

During mediating processes which occurs between stimuli and responses, children observe the people around them behaving in various ways. Individuals that are observed are called models. In society, children are surrounded by many influential models, such as parents within the family, characters on TV, friends within their peer group and teachers at school. These models provide examples of behavior to observe and imitate. Children pay attention to some of these people (models) and encode their behavior. At a later time they may imitate (i.e. copy) the behavior they have observed (Mcleod, 2016).

As regards to the behavior which is learned from the environment through the process of observational learning, Bandura's social cognitive theory states that there are four stages involved in observational learning. These are the attention, retention, initiation and motivation. With respect to attention, the observers cannot learn unless they pay attention to what's happening around them. This process is influenced by characteristics of the model, such as how much one likes or identifies with the model, and by characteristics of the observer, such as the observer's expectations or level of emotional arousal.

In the retention or memory of the aspect of the observational learning, the observers must not only recognize the observed behavior but also remember it at some later time. This process depends on the observer's ability to code or structure the information in an easily remembered form or to mentally or physically rehearse the model's actions.

In the initiation or motor in observational learning, the observers must be physically and intellectually capable of producing the act. In many cases the observer possesses the necessary responses. But sometimes, reproducing the model's actions may involve skills the observer has not yet acquired. It is one thing to carefully watch a circus juggler, but it is quite another to go home and repeat those acts.

Motivation an aspect of the observational learning, Bandura clearly distinguished between learning and performance. Unless motivated, a person does not produce learned behavior. This motivation can come from external reinforcement, such as the experimenter's promise of reward in some of Bandura's studies, or the bribe of a parent. Or it can come to vicarious reinforcement, based on the observation that models. High status models can affect performance through motivation.

According to Bandura, observational learning leads to a change in an individual's behavior along three dimensions, where an individual thinks about a situation in different way and may have incentive to react on it; the change is a result of a person's direct experiences as opposed to being in-born, and for the most part, the change an individual has made is permanent.

The social learning theory (SLT) approach takes thought processes into account and acknowledges the role that they play in deciding if a behaviour is to be imitated or not. As such, SLT provides a more comprehensive explanation of human learning by recognising the role of mediational processes. However, although it can explain some quite complex behavior it cannot adequately account for how we develop a whole range of behavior including thoughts and feelings. We have a lot of cognitive control over our behavior and just because we have had experiences of violence does not mean we have to reproduce such behavior (Bandura, 1986). It is for this reason that Bandura modified his theory and in 1986 renamed his Social Learning Theory, Social Cognitive Theory (SCT), as a better description of how we learn from our social experiences (Mcleod, 2016).

Some criticisms of social learning theory arise from their commitment to the environment as the chief influence on behaviour. It is limiting to describe behavior solely in terms of either nature or nurture, and attempts to do this underestimate the complexity of human behavior. It is more likely that behavior is due to an interaction between nature (biology) and nurture (environment).

Social learning theory is not a full explanation for all behaviour. This is particularly the case when there is no apparent role model in the person's life to imitate for a given behaviour (Mcleod, 2016).

2.12 Educational implications of Bandura's social learning theory

The educational implications of Bandura's social learning theory are that

- students learn a great deal simply by observing other people. This implies that teachers (models in the classroom) are to set or model appropriate behaviors and take care that they do not model inappropriate behaviors. With regards to this study, since I want to instill good problem solving skills into the target group, applying this theory demands that I personally show a positive attitude towards problem solving. I am to use the correct order and procedures to solve a problem in the class for the students to observe and imitate;
- describing the consequences of actions can effectively increase the practice of appropriate behaviors and decrease inappropriate ones. This can involve discussing with learners about the rewards and consequences of various behaviors. This point of bandura's social learning can be applied in this study by discussing the various aspect of problem solving with the students. When students are shown the correct way of solving a problem and the benefits of solving problems, they will easily follow the correct order;
- teachers should expose students to a variety of other models. This implies the use of different teaching styles to suit each member of the class. Hence in this study, since the focus is helping students to improve their performance in physics through the use of problem solving heuristics, the

researcher would have to introduce the students to several problem-solving heuristics;

- students must believe that they are capable of accomplishing tasks. Thus it is very important to develop a sense of self efficacy for students. Teachers in this regards are to help students to set realistic achievable goals. When students realize that they have been able to completely and satisfactorily accomplish a task, it boosts their confidence to start a new task. This helps to improve their self-efficacy (Mcleod, 2016).

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter outlines the research methodology used for the study. Thus the chapter describes the design of the study, which includes the pre-intervention, intervention and post-intervention activities that were carried out in the study. It also provides a description of the population of the study, the sampling technique and the size of the sample, data collection instrument, how data was collected and analysed. The study sought to investigate effect of incorporating problem solving heuristics in the teaching of physics on the academic performance in that subject.

3.1 Research Design

Research design is a plan and structure of the investigations to obtain evidence to answer research questions (McMillan & Schumacher, 1997). The design of a study is defined by Punch as the basic plan for a piece of empirical research (Punch, 2006). Among the ideas that are included in a design are the strategy, who or what will be studied, the tools and procedures to be used for collecting and analysing empirical materials (Punch, 2006). Action research design was adopted for this study. According to Cohen, Manion and Morrison (2008), an action research is the small scale intervention in the functioning of real world and a closed inspection of the effects of such intervention. Also Walsh (2001) defined an action research as a strategy for investigating and solving problems and introducing an educative change. Walsh further indicated that action research is a strategy that provides an opportunity to identify problems, find solutions and evaluate the effect of possible solutions. Ferrance (2000) proposed that an action research refers to a disciplined inquiry done by a teacher with the intent that the research will inform and change his or her practices in the future. Action research design was chosen because the study was aimed at improving students' performance in some selected concept in physics. This design also aided the Researcher to investigate some factors or problems that appear to hinder students' performance in physics. The Researcher developed a strategy to aid improve the situation at hand in the class. The focus was on improving the academic performance of the students through the incorporation of problem solving heuristics in the lessons. The Researcher chose action research because the focus was in line with the purpose and the intents of an action research. The purpose was to identify some difficulties students encounter at physics problem solving and the intent of the study was to develop a strategy to help students to overcome such difficulties.

The study was carried out in three phases which was cyclical in nature. All the three phases were expected to lead to learning outcomes. The diagram below shows the phases of the design of the study.

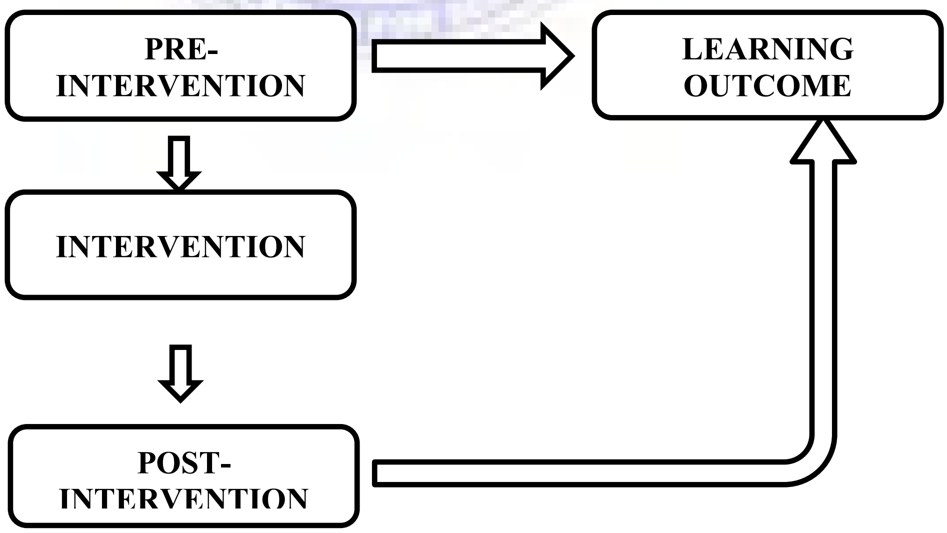

Fig. 1. Cyclic nature of the phases of the study design

Figure1 shows the cyclic nature of the phases of the study design. The study began with a revision of some previous learnt concept in physics after which a pre intervention test was administered to students to answer. The researcher used a checklist self-developed to help to monitor the manner in which students answer physics questions with the view of finding solutions to the perceived problems of the students. Lesson plans were developed and used in teaching students for six (6) weeks during the intervention stage. At the end of every week, students were made to take a test. The students output were monitored using the checklist.

Phase one was the pre- intervention stage. During this stage, physics exercise books of students were examined and some concepts in physics learnt previously were selected for revision. Through this process, two checklists, one for monitoring students' performance and the other for monitoring students' interest at physics lessons were developed. At the end of the revision, a test was conducted termed as the pre intervention test.

The second phase was the actual intervention meant to enhance students' knowledge in those selected physics concepts. During this phase, lesson plans were developed incorporating problem solving heuristics in the teaching of the planned lessons. The guidance and counselling coordinator of the school was made to monitor the students interest at physics learning throughout the lessons using one of the checklist (the attitude monitoring form) developed in phase one.

A post intervention test administered at the end of the intervention stage represented the third phase of the study, the post intervention phase. This test was aimed at evaluating the effect of the interventional strategy on performance.

Through this test the overall performance of students were assessed to check if the intervention tool had an impact on the students understanding. The checklist that was developed during the phase one stage was used to monitor students' performance and interest towards physics lessons at the end of the intervention stage.

3.1.1 Phase One Activities

This phase consisted of four activities which were done to identify the level of students' performance and problem solving skills in physics. The first activity the Researcher did was to collect the notebooks and exercise books of the students to assess their knowledge level in those selected topics in physics previously learnt and also the problem solving skills of students through the way they answered those physics questions. This gave the Researcher the opportunity to obtain a general view of the performance and problem solving skills of the class. The second activity was the revision of some of the concepts learnt in the previous term. These concepts included relative velocity, momentum, moments of a force and refraction of light. The lesson took place in the second week of the study with most of the learning activities being oral interactions of the Researcher with the students. Students were made to describe how refraction of light occurs. Also, students were made to explain the various types of collisions and to state the conditions necessary for a body to be in a static equilibrium. The students were also made to solve problems related to the topics discussed. The problems given to them involved calculations of the velocity of bodies after collision, relative velocity and moment of an applied force. The third activity involved the development of a checklist and a students learning progress monitoring form to assess and monitor how students answer physics questions. The checklist that was designed to assess how students tackle a physics problem presented to them had the following details. For every problem, the Researcher allotted 2marks for specific skill expected of the students to execute a task. Those who perfectly demonstrated the expected skill were awarded the full two (2) marks. Students who could not fully demonstrate the skill were awarded one (1) mark and those who were not able to demonstrate the expected skill or failure to perform the task attracted zero (0).

The criteria which the researcher focused on to help instil or infuse problem solving skills in the students are outlined in Table 1

Table 1: Marks distribution of expected skills

Skills	Marks
Ability to list the known and unknown quantities	
Ability to draw free body diagram if possible	2
Knack to select appropriate relation or formula	2
Ability to make the unknown quantity the subject of the	2
equation	2
Ability to substitute in known values and solve for	2
unknown	2
Correctness of answer numerically	2
Correctness of answer dimensionally	

The last activity in phase one was conducting a pre intervention test based on the last term's topics that were revised.

3.1.2 Phase Two Activities

Weekly lesson plans were developed with respect to the Ghana Senior High Schools Physics syllabus for second term. According to the 2010 physics syllabus for Senior High Schools in Ghana, students were supposed to learn Direct Current Circuit concepts, Thin Lenses, Thermal properties of matter and Calorimetry in the second term of the second year. Therefore lesson plans about these topics were developed systematically specifying the instructional objectives to be achieved each week. Problem solving heuristic was incorporated during the teaching of these topics. In order to help students develop the expected skills in problem solving, the problem solving heuristic proposed by Williams, Metcalfe, Trinklein and Lefler (1986), called the Modern Physics Problem Solving Rule, was adopted. This heuristic of problem solving has been explained into detail in the literature review. It is summarized below into five steps. These are visualising and describing the problem, finding a plan for solving the problem and executing the plan, and finally evaluating the answer to the problem.

Visualizing the problem is about translating the worded problem into a visual representation through

- drawing a sketch (or series of sketches) of the situation
- identifying and listing the known and unknown quantities and constraints
- identifying a general approach to the problem based on the type of physics concepts and principles that are appropriate in that situation

Describing the problem means translating the sketch(s) into a physical representation of the problem by way of

- using the identified principles to construct diagram(s) with coordinate system for each object at each time of interest

- specifying symbols the relevant known and unknown variables
- specifying the target variable

Finding a plan for solving the problem is the translation of the physics description into a mathematical representation of the problem. This is achieved by

- starting with the identified physics concepts and principles in equation form
- applying the principles systematically to each object and type of interaction in the physics description
- adding equations of constraint that specify the special conditions that restrict some aspect of the problem
- working backward from target variable until you have determined that there is enough information to solve the problem
- specifying the mathematical steps to solve the problem

Translating the plan into a series of appropriate mathematical actions is the execution of plan stage, which involves the

- use of the rules of mathematics to obtain an expression of the desired unknown variable on one side of the equation and all the known variables on the other side
- substitution of specific values into the expression to obtain an arithmetic solution

The final stage is the checking and evaluating the correctness of the obtained answer to the problem based on its sensibility. This is done by checking whether the solution to the problem is complete, including appropriate signs and units. It also includes the evaluation of the reasonability of the magnitude of the obtained answer

It was from this problem solving heuristic that the checklist for monitoring students' learning progress in problem solving was developed. Marking of tests were strictly based on these steps. Those who did not apply the steps or jumped some steps when solving a problem attracted a low mark.

3.1.3 Phase Three Activities

Phase three activities included the evaluation of intervention strategy. A post-intervention test was administered to the students to assess their overall performance and to check if the intervention tool had actually impacted on the students understanding. The test consisted of all the topics treated during the interventional activities. The test items comprised essay type questions. An essay type questions were chosen because they measure complicated learning outcomes and also stress on the integration and application of thinking and problem solving skills. According to Davis (1993), students preparing for essay tests focus on general concepts, broad issues and interrelationships rather than on specific details and this result in better students' performance as well as an improved problem solving skills. Students' outputs were monitored by the Researcher based on their responses to the questions in the tests with the aid of the students' learning monitoring checklist. Their responses were judged whether they were related to the required skill expected of them for the questions asked and whether explanations reflected understanding of concepts learnt. The results from this activity served as a basis for evaluating the performance of students and the intervention strategies implemented.

3.2 Population

Kannae (2004) defines population as the entire groups of individuals from which a sample may be selected for statistical measurement. Neuman (2003) also defined population as the group of interest to the researcher to which he/she would like the research result to be generalized. From the two definitions, a researcher is exposed to two types of population, the target population, which represent all the members of a real or hypothetical set of people to which we wish to generalize the result of a research and the accessible population which refers to the available population from which the researcher can realistically select from (Castillo, 2009).

In this study the target population consisted of all SHS science students in the Agona East District .The accessible population was the science students in Kwanyako Senior High School. The school has a total number of one thousand three hundred and four students. Out of this number, 143 were science students representing 11% of the total school population.

3.3 Sample and Sampling Technique

Jack and Norman (2003) indicated that most populations are large diverse and scattered over a large geographical area. In order to locate or contact all members within a particular population can be time consuming and expensive. Due to this researchers often select a sample to study. A sample is defined by Gay (1987) as a number of individuals selected for a study in such a way that the individuals represent a larger group. This implies that a sample must always be a representation of the population.

The sample from the accessible population for this study was all form two (2) science students at Kwanyako Senior High School. The class consists of forty eight (48) students out of which thirty two (32) were males and sixteen (16) were females.

According to Castillo (2009), sampling techniques are the strategies applied by researcher during the sampling process. Kannae (2004) suggested that there are two major types of sampling. These are probability sampling and non-probability sampling. Probability sampling is the one which the subjects of study are drawn from a larger population in such a way that the probability of selecting each member of the population is known (Macmillan & Schumacher, 1997). Methods of probability sampling include simple random sampling, systematic sampling, stratified random sampling and cluster sampling. Non-probability sampling on the other hand is a sampling technique used when probability samples are not required or appropriate or it may not be feasible to select subjects from larger group. Some of the non-probability sample techniques include convenience, quota and purposive sampling techniques. Convenience sampling is about a sampling technique in which a group of subjects is selected on the basis of being accessible or appropriate. A type of sampling technique whereby the researcher selects subjects on the basis of the characteristics of the population is termed as Quota sampling. Purposive sampling technique according to Cohen and Morrison (2008), is a sampling technique in which the researcher handpicks the cases to be included in the sample on the basis of judgement of their typicality.

In this study, the purposive and convenience sampling techniques were used in obtaining the sample for the study. Form two (2) science students from

Kwanyako Senior High School were purposively selected for the study because they could be a perfect representative or informative about the study for the target population. These students were chosen due to fact that they had been exposed to some physics concept already unlike the form one science students. The form three students were also busily preparing for the 2016 May/June WASSCE examination. The form two science students were also conveniently selected because they were easily accessible to the researcher as their physics tutor.

3.4 Instrumentation

An instrument is any device used in the collection of data. Examples are questionnaire, interview, observation or checklist and test (Fraenkel & Wallen, 2009). The main instrument used in this study was class test. Checklist for monitoring students learning progress and interest towards physics lessons were developed respectively by the Researcher and used in obtaining some aspects of the data

3.4.1 Test

A test serves as an instrument used to measure students' performance in class. The researcher conducted two tests for gathering information before and after implementation of the intervention strategy. The rubrics of the tests were boldly and clearly written and also explained to students before they used the 45 minutes allotted to answer the questions in the tests.

3.4.2 Students Learning Progress Monitoring checklist

This instrument was developed by the Researcher mainly to collect information on students output in the pre intervention test and post intervention test. The data collected was used to ascertain the skills students adopt to tackle a problem given to them and also to determine the performance of students from the beginning of the study till the end of the intervention implementation. This form consists of some expected skills on which students' responses to questions were examined. Students responses to questions were examined whether they relate to the questions asked, describe the situation demanded by the questions, and reflect understanding of the concept learnt.

3.4.3 Students' interest monitoring checklist

This observation checklist form was developed to monitor the likely changes in the interest of students towards physics learning. Observation (watching what people do) would seem to be an obvious method of carrying out research in psychology. However, there are different types of observational methods, which are controlled observations, natural observations, and participant observations (Mcleod, 2015).

Controlled observations (usually a structured observation) are likely to be carried out in a psychology laboratory. Here, the researcher decides where the observation will take place, at what time, with which participants, in what circumstances and uses a standardised procedure (Mcleod, 2015). The researcher systematically classifies the behaviour they observe into distinct categories. Coding might involve numbers or letters to describe a characteristics, or use of a scale to measure behaviour intensity. The categories on the schedule are coded so that the data collected can be easily counted and turned into statistics.

Naturalistic observation (i.e. unstructured observation) according to Mcleord (2015), involves studying the spontaneous behaviour of participants in natural surroundings. The researcher simply records what they see in whatever way they can.

According to Mcleod (2015), participant observation is a variant of the natural observations but here the researcher joins in and becomes part of the group they are studying to get a deeper insight into their lives.

In addition to the above categories, observations can also be either overt/disclosed whereby the participants know they are being studied or covert/undisclosed where the researcher keeps his/her real identity a secret from the research subjects, acting as a genuine member of the group. With all observation studies an important decision the researcher has to make is how to classify and record the data. Usually this will involve a method of sampling. These methods are

- event sampling where the observer decides in advance what types of behaviour (events) she is interested in and records all occurrences. All other types of behaviour are ignored
- time sampling where the observer decides in advance that observation will take place only during specified time periods (e.g. 10 minutes every hour, 1 hour per day) and records the occurrence of the specified behaviour during that period only.
- instantaneous (target time) sampling. The observer decides in advance the pre-selected moments when observation will take place and records what is happening at that instant. Everything happening before or after is ignored (Mcleod (2015).

In general, observations are relatively cheap to carry out and few resources are needed by the researcher.

According to Saskatchewan (1994), an observation checklist is most appropriately used in situations where teachers wish to record information on explicit student behaviours, abilities, processes, attitudes or performances. For example, it can help to evaluate communication skills, cooperation skills, extent of participation and motor skills. Observation of students' learning involves preparation towards observing, observing, recording the behaviour and summarizing seen behaviours (Johnson, Johnson & Holubee, 1998). According to them, preparation for observation involves deciding which students' behaviour and actions to be observed, making a sampling plan, making an observation form or checklist and training observers where applicable. Observations were used to gather information about students' interest at physics lessons in this study.

Perhaps the most straightforward way of finding out about someone's attitudes would be to ask them. However, attitudes are related to self-image and social acceptance (i.e. attitude functions) (McLeod, 2009). In order to preserve a positive self-image, people's responses may be affected by social desirability. They may not well tell about their true attitudes, but answer in a way that they feel socially acceptable. Given this problem, various methods of measuring attitudes have been developed. However, all of them have limitations. In particular, the different measures focus on different components of attitudes such as cognitive, affective and behavioural. These components do not necessarily coincide (McLeod, 2009).

In this study, the researcher focused on the behavioural aspect of attitude towards the teaching and learning of physics. Various areas of students' behaviour were captured in the checklist. How students showed the behaviour were rated using a five point Likert type scale ranging between very good through to very poor. The five point Likert type scale was coded as Very good (5), good (4), Normal (3), Poor (2) and Very Poor (1). The researcher engaged the school counsellor to carefully observe students before, during and after the lessons in order to respond to the items honestly. The school counsellor was selected due to her in-depth knowledge about human psychology. The detail of the checklist is found in the Appendix B.

3.4.4 Validity of instrument

According to Golafshani (2003), validity describes whether the means of measurement are accurate and whether they are actually measuring what they are intended to measure. For the test items to be valid, the items were given to two experienced teachers who have taught physics for several years from two neighbouring schools, Swedru Senior High School in Agona Swedru and Winneba Senior High School in Winneba. The validation of the test items were done with the view that it would yield the appropriate result which could be useful for making decisions and judgment about the students' academic performance in physics as described by Gronlund and Linn (1990). The validity of the students' progress monitoring form was also assessed by a senior lecturer at the physics department of University of Education, Winneba.

3.4.5 Reliability

Reliability, according to William (2006), refers to the consistency or dependability of the measurement or the extent to which an instrument measures the same way each time it is used under the same condition with the same subjects. In order to determine the reliability of the instrument for the study, the instruments were pilot tested at Swedru Senior High School since it was located in the district within which the study was undertaken. 30 science students were used for the pilot testing of the instruments. The reliability analysis was performed and the reliability coefficient is summarized in the Table 2.

Table 2: The reliability coefficient of instruments

Instrument	Reliability Coefficient
Pre intervention test	0.76
Post intervention test	0.78

According to Bork, Gall and Gall (1993), coefficient of reliability values above 0.75 are considered reliable. The reliability coefficients of both the pre intervention test and post intervention test were above 0.75, hence the indication that the instruments used for the study were reliable.

3.5 Data collection Procedure

Data collection is the process in which data for a study is gathered. It is also the systematic approach in gathering and measuring information from a variety of sources to get a complete and accurate picture of an area of interest (UNECE, 2000). Data collection enables a person or organization to answer relevant questions, evaluate outcomes and make predictions about future probabilities and trends.

Two forms of data were collected in the study. One form of the data was collected about the performance of the students and the other was on the interest toward the learning of physics. The data on academic performance was collected in two stages. The first stage was data collected on the pre-intervention test. Before the implementation of the intervention, concepts learnt by the students in the previous term were revised and at the end of the revision, students were made to write a test on the topics revised. The test was marked and data was collected with the help of the students' learning progress monitoring forms.

The second stage involved collection of data on students' outputs in the post intervention test activity with the aid of the same students' learning progress monitoring form. Also during the intervention period, exercises given to students were marked and expected skills assessed.

The second data was on the interest of students at physics learning. Here, an attitude monitoring checklist was used to assess the interest of students towards the learning of physics from the beginning to the end of the study.

3.6 Method of Data Analysis

Data analysis is the process of converting raw data collected into usable information (Statistics Canada, 1998). This study employed only quantitative method of data analysis even though certain aspects of qualitative learning abilities were convoluted in the study. Data from the pre-intervention test and the post-intervention test were analysed quantitatively using simple frequency counts and simply percentages after which the SPSS version 20.0 was used to calculate the mean scores and standard deviations of the pre intervention test and post intervention test. Independent sample T- test was also used for analysis of the data collected but much attention was paid on the significant differences in the mean scores with the use of the p-value. The numbers of students who showed understanding and hence executed the expected skill were counted and converted into frequency and percentage data. Data collected on students' interest was organized in a form of Likert type scale, for easy analysis. Thus descriptive analysis was performed on the data obtained to establish conceptual change and learning behaviour of students in order to determine the effect of the implemented intervention activity on the interest of the students towards physics learning.

CHAPTER FOUR

RESEARCH FINDINGS/RESULTS

4.0 Overview

The chapter is about the data obtained from the study and its analysis. It starts with the demographic description of participants of the study and continues with the analysis of the data obtained through the pre-intervention and post-intervention tests. The final part of the chapter discusses the findings of the study.

4.1 Demographic Description of Participants for the study

The classification of people into groups using common characteristics such as age, gender, income level, or race is referred to as demographic description (Lee & Schuele, 2010). Demographic description of respondents helps in providing data regarding research participants and also aid in the determination of whether the individuals are a representative sample of the target population for generalization purposes (Lee & Schuele, 2010). The participants of this study were classified in terms of gender and age. Tables 3 and 4 respectively show the age and gender of the students that were involved in the study.

Table 3: Age of participants

Age of student	Frequency	Percentage (%)
15	4	17.4
16	7	30.4
17	11	47.8
18	1	4.4
Total	**23**	**100**

The frequency and percentage count from the table indicate that most of the students were between the ages of sixteen (16) and seventeen (17) years. Out of twenty three (23) students eighteen (18) of them representing 78.2% were at the ages of sixteen and seventeen. Only 4 of them representing 17.4% were at the age of 15 and one of them was eighteen years old. With the structure of the Ghana education system, a child usually starts schooling at an average age of six (6) years. It is therefore expected that a student in form two (2) in the senior high school should be at the age of sixteen (16) or seventeen (17) years. The demographic data presented in Table 4 shows that majority of the students for the study fell within the standard age for that academic level in Ghana.

Table 4: Gender of students

Gender	Frequency	Percentage (%)
Male	21	91.3
Female	2	8.7
Total	**23**	**100**

Kwanyako SHS two (2) science class at the time of the study was a male dominated class. Out of the total 23 students, 21 of them representing 91.3% were boys whiles only 2 were girls. The enrolment of boys in the science class in the second cycle institutions has always been higher than girls. Perhaps this is due to the perception of the Ghanaian society that science is a difficult subject to study as such only boys have the valour to pursue that course.

4.2 Analysis of Data

In this section, the data generated from students pre-intervention test and post-intervention test results through the use of the students' learning progress monitoring form, observation checklist regarding their interest towards physics were analysed in order in which the research questions were presented in this study. Detailed discussions have been made on the outcomes of the pre-intervention test and the post-intervention test results in the succeeding parts of this chapter.

4.2.1 Analysis of the data with Respect to Research Question One

The analysis of data obtained to answer the research question one is presented. The research question one is on performance of students in some selected topics in physics before the intervention was implemented.

RQ 1: What is the academic performance of science students in physics before the incorporation of problem solving heuristics in teaching of physics?

This question sought to find out the performance of students in physics and also to assess the manner in which students tackle and answer physics problems that are given to them. Students' scores in the pre-intervention test with reference to the grading criteria developed aided the Researcher to obtain an answer to the above research question. After the conduction of the pre-intervention test, the Researcher carefully marked the students' script using the grading criteria. The number of students obtaining a particular mark, which were converted into percentages at that marks is shown in the Tables 5. The pre-intervention test was made up of two questions which were analysed separately and after which the total performance of the students was analysed. Question one was based on the concept of collision. Table 5 indicates how students answered question one of the pre-intervention test.

Table 5: Frequencies and percentages of student obtaining a particular mark for question one of the pre-intervention test.

Skills	Marks obtained		
	0	1	2
Ability to list the known and unknown quantities	19(83%)	3(13%)	1(4%)
Ability to draw free body diagram if possible	19(83%)	3(13%)	1(4%)
Capacity to select appropriate relation or formula	1(4%)	8(35%)	14(61%)
Ability to make the unknown quantity the subject of the equation	23(100%)	-	-
Ability to substitute in known values and solve for unknown	4(18%)	10(43%)	9(35%)
Correctness of answer numerically	18(78%)	-	5(22%)
Correctness of answer dimensionally	21(91%)	-	2(9%)

From the above data, only one person scored the maximum mark of 2 for listing all the known and unknown values in the problem before solving it. The rest of the students that is 19(83%) failed to list them. Very few of them (3) listed some quantities but failed to capture all of them. It was also noted that only one person made a free body diagram to simplify the problem before solving it. The remaining 19 students representing 83% failed to draw a diagram and three (3) students tried drawing but it was a wrong diagram and this led to some of them to mess up with the right equations needed to solve the problem. However it was realized that 14 students representing 61% were unable to write the appropriate formula, a proof that students were conceptually knowledgeable. For the requirement of making the unknown quantity the subject of the equation before substituting the known values, all 23 students scored zero. This is perhaps an indication of a bad problem solving skills on the part of the students. Majority of the students were able to substitute the known values into the equations they selected. Only 4 students failed to do so.

Two things were considered during the answer checking. These were the numerical reasonability and validity of the units attached. From the data presented in Table 4, it was found that 5 (22%) students gave a reasonable answer in terms of figure while 18 of the students representing 78% obtained zero mark. With regards to the correctness of the answer dimensionally, 91% of the students scored zero mark and only 2 students attached their answers with the correct units.

Question two (2) of the pre-intervention test required that students solve a problem regarding the concept of moment of a force. The responses obtained from students are summarised and shown in Table 6.

Table 6: Frequencies and percentages of students obtaining a particular mark for question two of the pre-intervention test

Skills	Marks obtained		
	0	1	2
Ability to list the known and unknown quantities	20(87%)	-	3(13%)
Ability to draw free body diagram if possible	23(100%)	-	-
Capacity to select appropriate relation or formula	8(35%)	-	15(65%)
Ability to make the unknown quantity the subject of the equation	13(57%)	-	10(43.5%)
Ability to substitute in known values and solve for unknown	10(43.5%)	3(13%)	10(43.5%)
Correctness of answer numerically	14(61%)	-	9(39%)
Correctness of answer dimensionally	12(52%)	-	11(48%)

In Table 6, a similar trend can be observed just as in Table 5. Only 3 students out of the 23 listed all the known and unknown quantities from the question before solving the problem. The remaining 20 (87%) failed to list the known and unknown quantities from the problem statement. All 23 students failed to draw a free body diagram to simplify the problem at hand. With regards to the selection of appropriate equation, 15 of the students representing 65% of the class scored the expected maximum mark of 2. This again confirms that students were conceptually knowledgeable. Three (3) of the students scored 1 mark with regards to the selection of appropriate equation simply because they used different alphabets in place of those that are normally used without defining them. Concerning the substitution of the known values and solving for the unknown quantity, 10 students scored zero mark. This perhaps demonstrates their weak mathematical background. Nine (9) students representing 39% scored 2 marks for giving a reasonable answer in terms of magnitude or figure. The answers provided by the remaining 61% of the students were totally out of range and therefore scored zero mark. Also, 11 of the 23students attached the correct units to their answer for question two. The remaining 12 students obtained zero mark for providing wrong units.

4.2.2 Overall performance of students in the pre-intervention test

The overall performance of the students in the pre-intervention test is presented in Table 7.

Table 7: Overall Mean Score of students in the pre-intervention test

Test	Mean	N	Std. Deviation	Std. Error
Pre- Test	8.43	23	3.09	0.64

The total score for the pre-intervention test was 20 marks. The overall mean score of the students is 8.43 as indicated in Table 6. In terms of percentage, this represents 42.5% which was below half of the total mark. Hence the pre-intervention test data indicate that the students' performance in physics fell below expectation.

4.2.3 Analysis of the data with Respect to Research Question Two

The analysis of data obtained to answer the research question two is presented. The research question two is on performance of students in some selected topics in physics after the implementation of the intervention.

RQ 2: To what extent will the incorporation of problem solving heuristic in the teaching of physics improve students' performance?

This question sort to find out the impact problem solving heuristic may have on the academic performance of students when it is incorporated in the teaching of the subject. A particular heuristic was adapted and incorporated during the teaching of some selected topics in physics for six (6) consecutive weeks. A class test was conducted termed the post-intervention test to examine whether the intervention has had an impact on the students' performance in physics. This test also comprised two questions. Question one was based on the concept of thin lenses. Table 8 presents the data obtained from the answers to question one of the post-intervention test.

Table 8: Frequencies and percentages of students obtaining a particular mark for question one of the post-intervention test.

Skills	Marks obtained		
	0	**1**	**2**
Ability to list the known and unknown quantities	-	2(9%)	21(91%)
Ability to draw free body diagram if possible	-	2(9%)	21(91%)
Capacity to select appropriate relation or formula	1(4%)	-	22(96%)
Ability to make the unknown quantity the subject of the equation	4(17%)	-	19(83%)
Ability to substitute in known values and solve for unknown	3(13%)	6(26%)	14(61%)
Correctness of answer numerically	6(26%)	-	17(74%)
Correctness of answer dimensionally	4(17%)	-	19(83%)

As shown in Table 7, 21 students representing 91% listed the known and unknown quantities from the problem statement correctly and also drew a free body diagram before recommencement to solve the problem. This perhaps shows acquisition of some skills from the incorporation of problem solving heuristic in the teaching of the topics. The knowledge acquired for listing the known and unknown values and making reasonable free body diagram might have enabled majority of them to simplify the problem. Hence with the conceptual knowledge students had, almost all were able to identify and select the right formula in order to substitute in appropriate values to solve the problem. Nineteen (19) of the students did very well by making the unknown quantity the subject of the equation before substituting the known values. Amid those who correctly did the substitution of the known and unknown values into the selected formula, 14 of them representing 61% were also able to perform the algebra. However 17 of the students had the magnitude of the correct answer. This implies that three (3) students who did not do correct substitution also managed to obtain the correct answer. These three students might have copied the correct answer from their friends. Also with regards to the unit of the answer, 19 students attached their answer with the correct unit.

Question two of the post-intervention test was a problem on the concept of Direct Current Analysis. The summary of responses of students with respect to the grading criteria has been presented in Table 9.

Table 9: Frequencies and percentages of students obtaining a particular mark for question two of the post-intervention test

Skills	Marks obtained		
	0	1	2
Ability to list the known and unknown quantities	1(4%)	2(9%)	20(87%)
Ability to draw free body diagram if possible	-	3(13%)	20(91%)
Capacity to select appropriate relation or formula	1(4%)	-	22(96%)
Ability to make the unknown quantity the subject of the equation	6(26%)	-	17(74%)
Ability to substitute in known values and solve for unknown	3(13%)	6(26%)	14(61%)
Correctness of answer numerically	6(26%)	-	17(74%)
Correctness of answer dimensionally	6(26%)	-	17(74%)

For question two of the post-intervention test, students obtaining maximum mark of 2 for each category of the requirement in the grading criteria ranged from 14 (61%) to 22 (96%). This is an outstanding improvement. For instance, twenty (20) students representing 87% listed all the known and unknown values correctly and made reasonable free body diagrams before carrying on with the solution to the problems. This might be due to suitable 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 streamlined the problems. Hence many students were able to identify the right formula and were able to substitute in the correct values to solve the problems. Considering the category of making the unknown quantity the subject of the equation before substituting the known values into the working equation, 17 (74%) of the students were cautious to this task and were able to execute it perfectly. The students had just done what Hollabaugh (2010) suggested. According to Hollabaugh (2010), one way of developing problem solving skills is by solving the basic equation for unknown quantities in terms of those given in the problem before substituting the given data into the working equation. Also, fourteen (14) students representing 61% were able to substitute in the known values into the working equations to solve for the unknown. Seventeen (17) students (i.e. 74%) gave reasonable answers in terms of figure and correct units to their answers. From the above results, it can be concluded that students had become competent in solving problems considering their performance in the post- intervention test.

4.2.4 Overall performance of students in post-intervention test

The overall performance of the students in the post-intervention test is presented in Table 10.

Table 10: Overall mean score of students in Post-intervention test

Test	Mean	N	Std. Deviation	Std. Error
Post- Test	16.09	23	2.68	0.5

From the Table 10, the overall mean score of students for the post-intervention test is 16.09. This value is equivalent to 80.5% which is above average. This is an indication that the incorporation of problem solving heuristic in the teaching of physics had a great impact on the academic performance of the students in the topics.

In order to determine whether the performance between students' mean scores in the pre-intervention tests and post-intervention test were statistically significant, an independents-sample t-Test was conducted. Table 11 shows that there was a significant difference between the pre-intervention test and post-intervention test of the overall mean scores of the students.

Table 11: Comparison of overall mean scores for pre-intervention test and post-intervention test

	Mean Diff.	Std. Deviation	t	df	Sig. (2-tailed)
Post-test – Pre-test	7.65	0.41	2.68	22	0.000*

*p<0.05 significant at α = 0.05

The t-Test conducted on the two overall mean scores showed that the difference between students' mean score for the pre-intervention test and that of the post-intervention test was statistically significant. The difference was 7.65 at a p-value of 0.000 in favour of the post-intervention test. This connotes that indeed the intervention of incorporating problem solving heuristic in the teaching of the selected topics improved the performance of the students in those selected topics.

4.2.5 Analysis of the data with Respect to Research Question Three

The analysis of data obtained to answer the research question three is presented. The research question three is on the interest of students towards the study of physics both before and after the implementation of the intervention.

RQ 3. What influence will incorporation of problem solving heuristics in teaching have on the interest of students towards the study of Physics?

This question sought to investigate whether or not the interest of student towards physics teaching and learning changed when they were exposed to problem-solving instructional strategy. Students' interest towards physics teaching and learning were determined through the use of an observation checklist. On the checklist, eight different precincts of students' behaviour were captured. How students exhibited the behaviours were rated from very good to very poor coded 5 to 1. The observations logged during the first two (2) weeks were summarized and termed pre-intervention attitude value and the observations registered during the last two weeks of the study were summarized and termed post-intervention attitude value. Table 11 presents the values obtained for students' pre-intervention attitude during the first two weeks of the study.

Table 12: Pre-intervention attitude values of students towards physics

Attitude	Values	
	Week 1	**Week 2**
Attendance to class	3	3
Facial expressions before lesson	2	2
Attention during lesson	2	3
Answering of questions asked by the teacher	1	2
Asking of questions about concepts during lesson	1	1
Eagerness in working out a given problem	1	2
Submission of assignments	2	3
Facial expressions after lesson	1	2
Mean value	**1.6**	**2.4**

For the first week, the mean value for the students' interest towards physics was 1.6. With regards to the interest monitoring scale used, this value represents 32% of the total interest expected of students. The individual items for monitoring the interest of students also suggest that students had very poor attitude and interest towards the study of physics. For example, answering of questions asked by the teacher, students asking questions about the concept being taught, eagerness of students working out a given problem and facial expressions of students after lessons were all rated very poor, thus at a value of 1. It was only the attendance to class that was rated "normal", thus at a point of 3. The result of the first week of the study reflected the actual attitude and interest students had towards physics. This is because the Researcher had not introduced the students to any new technique which might have had an effect on the students' interest towards physics.

During the second week, behaviours such as attendance to class, facial expressions before physics lessons and asking of question during lessons remained the same as the first week. However, there was an improvement in some of the behaviours as attention during lessons, eagerness in working out a given problem, submission of assignment and facial expressions after lesson. This slight improvement affected the mean value for the students' interest towards physics. The mean attitude value for the second week was 2.4 corresponding to 48% of the total expected interest at physics. This value perhaps might be as a result of introducing students to problem solving heuristics. The mean value for the first and second week representing the pre-intervention attitude value of students' interest towards physics was 2.0. On the interest monitoring scale used, 2.0 correspond to poor interest towards physics.

The last two weeks' recordings of students interest towards the study of physics was the post-intervention attitude values. Table 12 present the recordings made during the 5th and 6th weeks of the study.

Table 13: Post-intervention attitude values of students towards physics

Attitude	Values	
	Week 5	Week 6
Attendance to class	5	5
Facial expressions before lesson	4	4
Attention during lesson	4	4
Answering of questions asked by the teacher	3	4
Asking of questions about concepts during lesson	4	5
Eagerness in working out a given problem	4	5
Submission of assignments	4	5
Facial expressions after lesson	4	5
Mean value	**4.0**	**4.6**

The mean attitude values for the 5th and the 6th weeks were 4.0 and 4.6 respectively. This is a remarkable improvement when compared to the 1st and 2nd weeks' mean values. For instance in week 5, behaviour such as attendance to class was rated "very good" at a value of 5. Those behaviours such as facial expressions before lessons, asking questions during lessons, eagerness in working out a given problem, submission of assignment and facial expressions after lesson were all rated "good" at a value of 4. This improvement might be as a result of the interest students had developed for the subject as a result of the strategy the Researcher employed in teaching of those selected topics.

A mega improvement can be observed for the 6th week where students scored higher values thus ratings of "very good" for majority of the items in the interest monitoring form. As a result the mean interest value for the post-intervention attitude was 4.3 which corresponded to 86% of the expected students' interest towards physics. On the interest monitoring form 4.3 fell between "very good" and "good". This rating is far better than the pre-intervention attitude mean value of 2.0 corresponding to "poor". The pre-intervention attitude and post-intervention attitude values were paralleled to comprehend if there were any substantial or significant difference in their mean values. The result obtained is presented in Table 13.

Table 14: Interest of students towards physics before and after the intervention

Interest Form	N	Mean	Standard deviation	Mean Diff.	P-value
Pre-intervention	23	2.0	0.56	2.3	0.027*
Post-intervention	23	4.3	0.42		

*p<0.05 Significance (α= 0.05)

The data in Table 13 indicates that the mean value of students' pre-intervention attitude was relatively lower than that of the post-intervention attitude values. In order to determine whether the difference between these mean values was statistical significant, a paired sample t-Test analysis was done. The results of the analysis showed that the difference was statistically significant at p-value of 0.027. This is a clear indication that students' interest towards the study of physics became higher after the incorporation of problem solving heuristics in the teaching of physics. The Researcher personally felt and observed this high interest in the numbers in students' attendance to class, facial expressions of students during lessons, attention of students drawn to lessons, the eagerness of students to participate in class, the enthusiasm attached in working out of a given problem, the early submission of assignments and facial expression of students after physics lessons.

4.3 Discussion of Results

The purpose of this study was to examine the effects of incorporating problem solving heuristic in the teaching of physics on the academic performance of science students. The results, as presented in earlier sections of this chapter were done and analysed in line with each of the research questions. This part of the chapter is devoted for the discussion of the results along the research questions.

Result with respect to question one indicated that the performance of the students before the incorporation of problem solving heuristics was below average. This result is in line with the chief Examiner's report for the May/June 2012 WASSCE which indicated that the performance of students in Physics is below average. This poor performance of candidates was attributed to poor reasoning and poor problem solving skills on the part of students and also ineffective teaching strategies on the part of teachers (Chief Examiner, 2012). Analysis of pre-intervention test scores revealed that students had a poor problem solving skills. The following observations were made before the implementation of the intervention.

1. Students skipped vital steps during problem solving thereby lost marks for those steps
2. Students who were able to work through to the final answer either had wrong units or attached no units to the answer.

3. Students rushed into solving problems without proper analysis hence unable to complete them.
4. Students appeared to forget the order of steps needed to solve a particular problem.

A research conducted by Caliskan, Selcuk and Erol (2010) on the effect of problem solving strategies on the academic performance of students in physics also made similar assertion as indicated in the observations above. These observations were also consistent with the findings of Taale (2011) in a study on the academic performance in physics of the students of Somanya Senior High Secondary Technical School in the Yilo Krobo District of Eastern Region of Ghana.

The findings of this study with respect to research question two revealed that incorporation of problem-solving heuristics in the teaching of physics was effective for augmenting physics achievement, problem solving performance and strategy use. The analysis showed that students improved on their performance since the average score of 42.5% rose to an average score of 80.5%. This result is consistent with the findings of a study on problem solving instruction in different subject areas at different grade levels, from secondary to university. The result shows consistency with the results of a number of studies that have examined the effects of problem solving strategies on problem solving. For instance, in physics, Larkin and Reif (1979) and Wright and Williams (1986) showed in their research that the teaching of problem solving strategies has a positive effect on students' academic performance. In conjunction with this, for example Sutherland (2002) in Chemistry, Perveen (2010) and Schurter (2002) in mathematics, all reached similar conclusions in their research studies. The finding of this study also provided empirical support to earlier findings made by Bodner (2000) and Domin, Camacho and Good (2001) which remarked that there is significant improvement in students' achievement when problem-solving is accompanied with corrective measures such as verbal feedback and teacher-directed remedial instruction. Other empirical studies which gave positive effects of problem-solving models on achievement in other science subjects include that of Martin and Oyebanji (2000), Decorte and Scriners (2002), and Payne (2004). The result of this research shows that the teaching of problem solving heuristic increased the level of students' knowledge in problem solving process. It can be said that the incorporation of problem solving heuristics in teaching is more effective in helping students improve their problem solving ability and hence academic performance. Detailed study of students' post-intervention test script revealed the skills the students had gained in solving problems. This reflected equally in the overall performance of students in the post-intervention test.

The results with respect to research question three revealed that incorporation of problem solving heuristic in the teaching of concept in physics had a great impact on the behavioural attitude (interest) of the students towards physics learning. The result indicated a low interest of students towards the study of physics before the implementation of the intervention. The mean score for pre-intervention attitude of 2.0 became evident that their interest was very low at physics learning. They also had no specific way of approaching a problem and so viewed physics as a very difficult subject. As physics is perceived by majority of the students to be difficult, they came to class with melancholy faces and appeared dull towards instructions. However after the implementation of the intervention there was a tremendous change in their interest towards physics. The score on the attitude/interest scale of 4.3 as seen in Table 13 indicate a positive change in attitude towards physics after the intervention. Once students mastered the techniques of approaching a problem, they appeared no longer affraid of participating in physics lesson. Students now entered classroom for physics lessons with cheerful faces and also were ever ready for any task. Students who once feared solving physics problems now ask for more exercises and assignments after the lesson had been taught. Assignments were submitted on time and also attendances were very encouraging, a sign that may be interpreted as interest for the subject. The interest of the students in the study of physics might have emanated as a result of the improved academic performance in the subject and also the ability to use a heuristic approach in solving problems in that subject. The findings of several studies show that there is a correlation between students' achievement in physics and their attitude or interest towards physics. For example, Kahle, Parker, Rennie, and Riley (1993), Baker and Leary (1995), Farenga and Joyce (1997) and finally Jones, Hove, and Rua (2000) all found out that there is a positive relationship between achievement in physics and attitude or interest. A study in Chemistry by Festus (2012) found out that there was a statistically significant difference between the problem-based learning and conventional groups in terms of their attitude towards chemistry, skills development and conceptual understanding. The findings of this study therefore suggest that students' physics achievements have a relationship with their attitudes or interests. Also the instructional approach used by the Researcher impacted positively on students' achievements as well as their attitude or interest.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Overview

This chapter is devoted to the summary of the findings of the study and conclusions drawn from the outcomes of the study. Recommendations and implications based on the findings of this study are also presented.

5.1 Summary of the study

Examining the effect on science students' academic performance in physics through the use of problem solving heuristics was the main focus of the study. Action research method was used for this study. The researcher developed lesson plans that incorporated problem solving heuristics in the teaching of some selected concept in physics. This was done after the researcher revised previously learnt physics concept with the students and followed it with a class test termed pre-intervention test. A grading criterion and an attitude monitoring checklist were developed to monitor how students tackle problems presented to them and the interest of the students at physics learning respectively. After marking students' pre-intervention test scripts, it was observed that majority of the students approached problems presented to them devoid of required skills and conceptual knowledge. Detailed findings were that

- Students rushed into solving problems without careful analysis of the problem given
- Students showed conceptual understanding but lacked the required problem solving skills to solve problems.

- Majority of the students were found to skip some steps and that the solutions were poorly organized.
- Most of the students ignored units to answers or attached wrong units.

These challenges of students in solving problems caused them to lose major marks leading to poor performance in physics. Statistical analysis of the scores obtained by the students revealed that the mean score of the students for the pre-intervention test was 42.3%. This indicated that the students' performance was below average. The poor performance negatively affected the interest of the students towards the learning of the subject.

After six weeks of intervention implementation, a test was conducted called the post-intervention test. The result from the analysis of the post-intervention test scores indicated that the mean score 16.09 equivalent to 80.5% was above average. It might be seen that students had acquired some skills in problem solving. For example, about 95% of the students listed all the known and unknown quantities involved in a problem statement before solving the problem. Students now solved problems in more skilful way. It was observed that the improved performance triggered a feeling of accomplishment in the students thereby positively affecting the interest of the students in the teaching and learning of physics. The perception of the students that physics appears too difficult had waned. Students who once feared solving physics problems now asked for more exercises and assignments after the lesson was taught.

5.2 Conclusions

The answers to the research questions presented in this study comprised an important step in understanding students' performance and interest towards the teaching and learning of physics, by underscoring the importance of regular incorporation of problem solving heuristics in the teaching of the subject and by identifying a connection between academic performance and the interest in learning of physics concepts

In the light of the results of the analysis obtained from this study, it can be deduced that incorporating problem solving heuristics in the teaching of physics has a positive effects on students' physics performance and interest in studying the subject. This was manifested in how students presented their class exercises and assignments and how they solved problems given to them. It appears students had developed interest in solving physics problems since they could remember and use the steps needed to solve the problems. Another conclusion that could be drawn from the study based on the performance of students is that the traditional method of teaching physics proved less effective than the problem-solving heuristic method. In addition, the problem-solving heuristic in physics learning improved the performance as well as the interest of students. If problem-solving instructional strategy could improve students' learning outcomes in physics, it would be necessary to vary the mode of instruction of teaching physics at the Senior Secondary schools so as to accommodate student–centred activity-oriented instructional strategy that might make physics students good problem-solvers, thereby improving the performance of students. 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 students have about physics cannot overshadow its relevance in terms of its usefulness in the society, and students' interest in the subject which may automatically lead to an increased physics student's enrolment in Ghanaian schools and colleges.

5.3 Recommendations

Recommendations from this study have been directed to Kwanyako SHS science teachers, other schools who want to incorporate problem-solving heuristics in the teaching of physics, CRDD, the Ghana Education Service (GES), the Ministry of Education and other stakeholders associated with science education.

From the study, the following are recommended to the school and the teachers who may want to include problem-solving heuristic methods in the teaching and learning of Physics

- ❖ Kwanyako SHS physics teachers should use innovative and easy-to-understand strategies in helping students develop problem solving skills. The steps involved in solving problems should be taught in class and should not be presumed that once students understand a concept they will be able to solve problems regarding such concepts. Instructors often assume that there are some students who will be able to acquire metacognitive skills on their own, while others lack the ability to do so (Pintrich, 2002). So, to help students develop their own problem solving skills during lessons, instruction using a problem-solving framework needs to make explicit the heuristics that are involved, and facilitate opportunities for students to make their own problem solving processes explicit. Teachers must plan to include some goals for explicitly teaching problem solving within their regular instruction of physics concept teaching. Because problem solving processes are largely implicit, one of the most important aspects is the explicit labelling of problem solving heuristics for students.

- In assessing students, teachers are recommended to set specific objectives and skills they want their students to develop and mark accordingly. In this case teachers would be much focused on such skills and help their students to acquire them accordingly.
- The Ministry of Education (MoE), GES and other stakeholders involved in science education should organize secondary school teachers who are already in service to be given adequate training through workshops, symposia, conferences and seminars to enhance and acquire better strategies of teaching physics. They should be taken through various heuristics of problem solving. This will aid them to select those heuristics that will be easy to teach and easy to be understood and used by students.
- When secondary school physics curriculum is opened for negotiation, it should include problem- solving and activity-oriented instructional strategies. Practical activities involving the use of ones' mental ability should be stuffed in the curriculum. This will aid both teachers and students to heuristically find approach to such practical activities
- Teachers should be encouraged to ensure that students are made more responsible for their own learning through group activities and discussions, sharing of ideas and cooperating with peers with some guidance from the teacher. This implies that Physics teachers should model their instructions to enforce student-student interactions. For instance, using problem-solving project packages that will enhance group

discussions or active learning among students. This will help students to develop a proper attitude towards problem-solving with a view to improving their performance in physics as well as making them functional to themselves and the society at large.

5.4 Suggestions for further studies

The following suggestions are proposed:

1. At different levels of education, research should be done into the effects of the teaching of different problem solving heuristics in physics classes and on the affective domain.
2. Research should be conducted in different fields where the relationship between the use of problem solving heuristics and its effects on the different variables such as age, sex, success level, socioeconomic and socio-cultural level etc.
3. Especially in the field of physics at different teaching levels, research should be conducted in depth with students, candidate teachers and even with teachers on their awareness and ability to use problem solving heuristic.
4. The effects of problem solving heuristics on the conceptual understanding of students in physics could be investigated using different assessment instruments such as conceptual tests instead of classical problem solving skills achievement tests.

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APPENDICES