UNIVERSITY OF EDUCATION, WINNEBA

USING CONSTRUCTIVIST APPROACH TO ENHANCE STUDENTS' PERFORMANCE IN SOLVING QUADRATIC EQUATIONS BY THE GRAPHICAL METHOD

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USING CONSTRUCTIVIST APPROACH TO ENHANCE STUDENTS' PERFORMANCE IN SOLVING QUADRATIC EQUATIONS BY THE GRAPHICAL METHOD: A CASE OF POTSIN T.I AHMADIYYA SHS

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DECLARATION

Student's Declaration

I, Elizabeth Oduro, hereby declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and duly acknowledge, 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 this work was supervised in accordance with the guidelines for supervision of Thesis as laid down by the University of Education, Winneba.

Name of Supervisor: Prof. S.K. Asiedu-Addo

Signature: ……………………………

Date: …………………………………

DEDICATION

I dedicate this research work to my beloved husband Mr. Dennis Nugbemadoh and my lovely children, Wanika Edem Nubemadoh and Alvin Elikem Nugbemadoh.

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ABSTRACT

The study sought to use constructivist approach to enhance the performance of students in solving quadratic equations by the graphical method. Quasi-experimental non-equivalent group with a pre-test and a post-test design was employed. Fifty-five (55) students were purposefully selected from two of the General Art Classes in Potsin T.I Ahmadiyya S.H.S in the Gomoa-East District of Ghana with a four weeks intervention program. One intact class was used as the control group comprising of thirty-two (32) students and the other as the experimental group comprising of twenty-three (23) students. Instruments used in the study were, diagnostic test, achievement test and an unstructured interview guide. The analysis of the pre-test and post-test scores were based on the quantitative data collected using descriptive and inferential statistics whiles the qualitative data were analyzed thematically. Results from the paired(independent) sample t-test indicated that there was a statistically significant improvement in the scores between students who were taught using the constructivist approach than those taught by the conventional approach. Analysis of the interview revealed that, the student-centered method made the lesson more interesting, very practical and motivational. The researcher identified five major difficulties students encountered when solving quadratic equations by the graphical method: finding tables of values, plotting of points in the Cartesian Plane, drawing of smooth curves, finding the axis of line symmetry, finding the solution set for the graph and finding the minimum point of the graph. The study recommended that the classroom practice which was more of teacher-centered approach should be discouraged and teachers should promote collaborative learning and encourage constructive conversation that allows students to share their views without being interrupted but to become better communicators and to be more open-minded students.

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CHAPTER 1

INTRODUCTION

1.0 Overview

This chapter covers the general background to the study, statement of the problem, purpose of the study, objective of the study, research questions and significance of the study. It also takes into consideration the limitations, delimitation and the organization of the study.

1.1 Background to the Study

Education is the process of acquiring knowledge and information that lead to a successful future and nation development. Education is a prominent thing that cannot be separated from human's life. It is the only bridge that leads people to their better futures and for that matter plays an important role in the development of a country. If a country does not have proper education, it may be left behind by other countries which support education and their very survival threatened. For this reason, the relevance of education cannot be overemphasized. The development of a country can be determined by whether its citizens have good education or not. The better the quality of education that a country has, the faster it is likely to develop. Countries such as United States of America, China, Japan, Britain, Germany, Korea, India and a host of other nations have achieved their economic breakthrough by providing quality science, mathematics, engineering and technology education to its citizens thereby scaling the poverty barrier of the nation. Because of this, every nation including Ghana is making effort to provide at least basic education for all children of school going age.

Since Ghana wants to develop rapidly, then there is the need for science, mathematics, engineering and technology to become the pivot of their education starting from the early childhood level. The 2007 educational reforms buttress this point as it clearly stated in the executive summary of the President's Committee on Review of Educational Reforms in Ghana "Meeting the Challenges of Education in the Twenty-First Century", (October 2002). That, the key to the future socio-economic development of Ghana lies in the development of science and technology education. Ghana has a growing need for a large number of scientists, engineers and technicians to bring about technological innovation required for her development and for the future development of science and technology. To achieve this, it is therefore important that mathematics and mathematics education must be given the number one priority since it forms the basis of many disciplines such as science, engineering science, home economics, agricultural science, business, marketing to mention but a few. Economic progress all over the world is based on science, engineering and technology where by their area of study cannot be separated from mathematics. In the history of education, mathematics has held its leading position among all other school subjects because, "Mathematics in education is the bedrock and an indispensable tool for scientific, technological and economic advancement of any nation" (Umameh, 2011). Mathematics play a vital role in the daily life of man all over the world. It is useful at our homes, in the workplace, in school, and in the community.

Mathematics has been proven to be the foundation of many businesses and professions and its importance cannot be ruled out in today's society. Mathematics is an important subject not only from point of view of getting an academic qualification at school or college, but also is a subject that prepares the students for the future as well, irrespective of which work of life they choose to be a part of (Davies 2012).

According to Mefor (2014), relates mathematics to everything in the universe from the smallest to the largest. Umameh (2011) also points out that mathematics is intimately connected to daily life and everybody's life-long planning. With all these attributes, it is therefore believed that education and human life cannot function properly without mathematics. Due to its importance globally, mathematics as a subject became key in the school curriculum.

According to Ngussa and Mbuti (2017), the mathematics curriculum is intended to provide students with knowledge and skills that are essential to the changing technological world. Mathematics is a subject that is studied in almost every part of the world. In Ghana, mathematics is given all the necessary importance in the curriculum and all policies related to education, right from primary to higher levels. Mathematics is one of the compulsory subjects that must be passed at credit level by students before getting admission into any tertiary institution (Universities, Nursing Colleges, Polytechnics and the universities of Education) in Ghana as well as the security services.

Mathematics is one of the core or basic subjects for all primary and senior high school children. For example, in the Ghana's Senior High School Curricula, there are four core subjects, notably; Mathematics, Integrated Science, English Language and Social Studies, (Ministry of Education, Science and Sports) and among these subjects, students see the mathematics subject as the most difficult subject and do not enjoy its teaching and learning. However, it is disheartening to note that with all the importance attached to mathematics, many young learners perceive mathematics as a "boring, irrelevant and very difficult subject". Smith (2004: 2), hence does not have any interest in studying it. Students perceive mathematics to be strange and too difficult to learn even though mathematics is important and practical for life. This perception cuts across all levels of education where mathematics is taught. Due to this perception, many students stay away from mathematics lessons, and others pretends to be sick deliberately, while others sit in the class and wait for the lesson to be over and so until solutions have been found to the problems by the use of alternative methods, students would continue to run away from mathematics.

This attitude of students towards mathematics can affects their performance in mathematics. When they show that poor performance in mathematics, it is a function of cross-factors related to students, teachers and the school environments. Among the student's factor are as a result of students not understanding basic mathematical concepts or don't see why mathematical procedures work or don't know when to use a given mathematical technique. Among the teacher's factor are teaching materials used by the teacher, teacher's classroom management, teacher's content knowledge and the approach to teaching of mathematics.

The most commonly teaching approach employed by teachers in the teaching and learning of mathematics in most public schools in Ghana is the teacher - centered approach (one-way communication) for which teachers in Potsin T.I Ahmadiyya Senior High School are no exception, the Teacher stands in front of the class and explain all the materials, while the students just sit down on their seats and listen to the teacher. In other words, the students become passive receivers of the information presented. Teacher - centered approach of teaching (One-way communication) has negative effects on the students. According to Boaler (2009), this approach to teaching and learning has been unable to produce students who are critical thinkers. Students who experience mathematics in this way are often unable to transfer the knowledge they have acquired in solving real-life problems. The students lack enough confident to share their views or even ask simple questions on the topic been taught.

Mathematics as a subject can be well understood by learners only when the right methodologies, adequate and appropriate teaching and learning materials, good facilities and right teaching techniques are employed in the teaching and learning process. Teaching methods that teachers use to deliver the curriculum in the mathematics classroom is an important variable to influence the performance of learners in mathematics and could also be a contributing factor not only to the learners' poor performance but also the reason for the learners' errors in the subject (Shulman, 1987). In flight of this, for many years the constructivist approach to teaching has appeared in mathematics textbooks, curriculum frameworks and literature as a backbone of the mathematics curriculum. The Constructivist's Mathematics curriculum encourages the use of different teaching methods in the mathematics classroom. The new mathematics curriculum which was introduced in 2007 echoed explicitly the need for a constructivist teaching approach (student-centered), to the teaching and learning of mathematics which aimed at promoting student's active participation and engagement in the teaching and learning process of mathematics in Ghanaian schools.

To Wheatley (1991) as cited by Abha, Sturt, Naruemon, Robert and Mohmaed (2012) research suggests that it is only through active engagement of students that the desired learning outcomes can be achieved. In order to achieve this, it is therefore necessary that close attention be paid to teacher's teaching and learning approach in the mathematics classroom. One of such approach is the constructivist teaching approach.

The constructivist teaching approach has emerged as a very powerful and effective model for explaining how students learn and how knowledge is produced in the world.

Constructivist teaching approach plays an important role in developing students' conceptual understanding and ability to communicate learned ideas, but it seems few teachers use this approach in most of the Ghanaian Mathematics Classrooms even though these teachers might have heard about the potential and the effectiveness of the use of the constructivist instructional strategies to improve student's academic performance. Some of these mathematics teachers feel hesitant to try the constructivist approach, probably because of the structure of the curriculum which has to be completed within a short period of time. Many a time, mathematics teachers are compelled to cover the topics in the syllabus or to get to the end of the book for examinations purpose without giving students the opportunity to acquire deeper understanding of the topics. They also think using constructivist instructional strategies requires additional planning. Teachers also feel using the constructivist approach allows the students to do most of the work themselves hence does not allow the teacher to finish the topics on time.

Notwithstanding, with all the importance and the effectiveness that has been associated with the use of constructivist teaching approach to improve student academic performance, however it is very discouraging to note that what most mathematics teachers feel about the use of this teaching approach has made the use of the constructivist teaching approach in instructional delivery very minimal in most Ghanaian mathematics classrooms.

Constructivism is a learning pedagogy that is student-centered and based on a learning theory that focuses on how students develop understanding. Constructivism is also the notion that children build knowledge from their own experience. (Richardson,1999). Constructivists believe that children develop knowledge through active participation in their learning process. In the constructivist teaching approach, learners are active participants in the learning process through interaction with others. The learners are encouraged to use their experiences or prior experiences to understand new information. The teacher in the constructivist learning theory is a facilitator who provides scaffolding to promote learning. For according to (Anghileri, 2006; Money, Fairhall & Trinck, 2007) describe scaffolding as a technique where the teacher takes control in facilitating and directing learning through the provision of cues, prompts, probes, among others and hands over the responsibility to the learners whenever they are ready.

Both teaching styles can lead to successful learning but it is reasonable to argue that the conventional teaching methods are not providing meaningful instructional options to help improve students' academic performance of the mathematics subject. Conventional teaching methods are known to limit learners' participation in the lesson and to be more teacher-centered in an attempt to chase the syllabus coverage. Due to the huge advantage the constructivist approach had over other teaching approach in the teaching and learning of mathematics, it would be imperative to consider the constructivist approach as an instructional tool to help elevate the academic performance of students in mathematics.

1.2 Statement of the Problem

Knowledge is not attained but constructed (Von Glasersfeld, 1991). This statement was made in response to a new challenge to the concept of traditional knowledge. Today, we are confronted with the challenge of a paradigm shift in public education in Ghana. Parents and the general public have criticized public schools and classroom environments, claiming that they are unprepared to meet the needs of students and the demands of the industrial society in this twenty-first century (21st) information society. Some criticize current educational practices, raising concerns about Ghanaian students' inability to engage in creative thinking and problem solving. tasks when compared to other advanced countries.

Ghana has experienced several curriculum reforms since becoming a democratic country in 1957. Despite these curriculum reforms, the performance of learners in Mathematics still remains a national concern. Statistics and research indicate that learners' performance in Mathematics in Ghana at the West African Senior School Certificate Examinations (WASSCE) and in the Trend in International Mathematics and Science Study (TIMSS) is persistently poor. For instance, in the 2003 TIMSS study, Grade 8 learners from Ghana participated alongside 45 countries in mathematics but was ranked among the lowest position (44th) in Africa and the world. Similarly, the 2007 and 2011 TIMSS mathematics average score of 309 and 331 respectively for grade 8 students from Ghana were lower than the low international benchmark average of 400 (Mullis, Martin, Foy & Arora, 2012).

Furthermore, the results of the West African Secondary School Certificate Examination (WASSCE) in mathematics have left much to be desired over the years. Students have consistently recorded massive failures in mathematics, which has been a source of concern for all teachers, parents, stakeholders and the nation as a whole. Methods used in teaching mathematics in the majority of Ghanaian schools since post-independence have not undergone significant change. In the guidelines for formulation and implementation of policies, and programs under education (Section 5.1.12), in the executive summary of Ghana's vision 2020 (titled The First Step) clearly states that the vision will substitute teaching methods that promote inquiry-based learning and problem-solving for those based on rote learning. This is one of the medium-term (1996-2000) policies under education that is yet to materialize and is long overdue.

From the researchers' own experience as a mathematics teacher at Potsin, T.I. Ahmadiyya Senior High School Gomoa-Potsin, the researcher realized that students in form two (SHS 2), have difficulty in "solving quadratic equations by the graphical method" which is also one of the factors of poor performance of students in the school. This was obvious after a diagnostic quiz organized by the researcher in the second year General Art Form Two class in term three in the year 2019. The nature of the questions was an application question where students are expected to complete the table of values given a quadratic equation in the standard form, plot the graph using the plotted values, interpret and analyze the graph. At the end of the quiz, out of 55 students in the class, 13(24%) out of 55 students scored above 10 marks out of 20 marks. These marks were considered as above pass marks whiles 42(76%) out of 55 students scored below 10 marks out of 20 marks of which was regarded as poor performance in solving quadratic equations by the graphical method.

It was then realized that students were having difficulties in the concept and theories of "Solving quadratic equation by the graphical methods". Students could not use the relations given to complete the values of table, some could not choose a suitable scale to work with, some could not have joined the ordered pairs plotted on the graph to get a smooth curve making the quadratic graph, the graphs were incorrectly drawn. Some of the shapes have sharp point, outward asymmetric curve, kink shape, s-shapes curve, flat nose and half cup-shapes. Again, most could not use their free hands to draw the attain quadratic curve neither could they interpret their own graphs. Through observation and interview from other mathematics teachers generally indicated that majority of the students do not have a good foundation of basic mathematics concepts, most of them also lack the concept of algebraic expression and the property of real number system. Further diagnoses also indicated that students' lack of understanding of solving quadratic equations by the graphical method could be as a result of inappropriate teaching and learning methodology used for teaching the concept algebra, geometry, linear equations and linear graphs, which are the relevance previous knowledge needed for the study of quadratic relations and graphs.

Again, in (2018/ 2019) academic year, a report of the final year students of Potsin, T.I. Ahmadiyya Senior High School Gomoa – Potsin, mock exams indicated that though the standard of the mathematics examination paper compared to the earlier years was quite good, yet still candidate performance remains poorer than expected however, there are still weakness in general in terms of answering questions on algebraic expressions, geometry and solving quadratic equations by the graphical method. Furthermore, the researcher also noticed that most candidates did not make any effort in answering question on solving quadratic equations by the graphical method even though it was compulsory, and for those who attempted answering, many of them could not handle the question as required. Further investigations proved that the students have persistent problem answering questions on graph in general and particularly solving quadratic equations by the graphical method. The situation above has therefor resulted in the poor performance of students of Potsin, T.I. Ahmadiyya Senior High School Gomoa – Potsin, in the area of mathematics over the years and if care is not taken, many of the students will continue to run away from mathematics class. Students already have the notion that mathematics is a difficult subject and do not enjoy the teaching and learning of the subject.

At the senior high school level, many topics are treated in the core mathematics syllabus, these topics includes, algebraic expression, sets, relations and functions, real number system, number bases, geometry, mensuration, quadratic functions among others. Formal definition and the concept of quadratic functions and equation as a content and a major topic with graph of quadratic equations as a sub-topic is generally taught to students once a student reaches Senior High School (SHS) form two (The Curriculum Research and Development Division (C.R.D.D) 2010, mathematics core syllabus for Senior High School). At the Senior High School level, teaching and learning activities of the following sub-topics are treated under solving quadratic equations by the graphical method; finding the range of value for given expression, plotting of points and drawing the curve of the given relations, using the graph to find the roots of the equation, finding the minimum and maximum values and points. finding the axes of the line of symmetry and also finding the increasing and decreasing values of x of the relation.

The topic "graph of quadratic functions" has been an integral part of the Senior High School mathematics syllabus because, a detail knowledge of graph of quadratic function is significant since its' application is needed later on in other subject of study in the school curriculum. It is important to learn quadratics because aspects of the quadratic function are used later on in higher mathematics classes when dealing with higher polynomial functions. Quadratic is not studied only for its knowledge but for its application to solve common issues in our everyday lives too. Quadratics relate to the mathematical thinking and reasoning in the real world due to being involved in describing the paths of projectiles (Brown, Breunlin, Wiltjer, Degner, Eddins & Edwards, 2007; Center, 2012). Thus, some of the practical values of quadratics are found in the area of paths of projectiles, appearing on suspension bridges over a river, being the cross-section of automobile headlights, satellite dishes, and radio telescopes, the military uses quadratics to predict where artillery shells will hit the earth, to describe the orbits along which the planets move to mention but a few. In business, quadratics can be used to maximize profit.

In view of the usefulness of the topic "quadratic equations" in the Senior High School mathematics syllabus, students of Potsin, T.I. Ahmadiyya Senior High School form two (2) class still experience difficulties in solving quadratic equations by the graphical method and interpreting these graphs.

After identity that students have difficulties and some challenges in the concept of solving quadratic equations by the graphical method, the researcher diagnosed the problem and it gave a course to search for the responsive instructional method to address learners' difficulty in solving quadratic equations by the graphical method in terms of exposing the difficulties and thereby providing a treatment for the observed difficulties. On this basis, the study investigated the use of Constructivist Instructional Approach to teach Potsin T.I Ahmadiyya SHS students to overcome their difficulty in solving quadratic equations by the graphical method. This study may help teachers to understand how students think mathematically and what kind of errors they make while solving quadratic equations by the graphical method and take precautions against them. It is also aimed to contribute to national literature regarding solving quadratic equations by the graphical method.

1.3 Purpose of the Study

The purpose of the study was to use constructivist approach to enhance students' performance in solving quadratic equations by the graphical method.

1.4 Objectives of the Study

The study was guided by the following specific objectives

1. To identify the difficulties and errors students encounter when solving quadratic equations by the graphical method.
2. To investigate the effects of constructivist approach of teaching to improve student's performance in solving quadratic equations by the graphical method compare to the conventional approach.
3. To find out the views of students on the effect of the use of the constructivist approach of teaching.

1.5 Research Questions

The following research questions were used to promote the study;

1. What are the difficulties and errors do SHS students make when solving quadratic equations by the graphical method?
2. What effect do constructivist approach of teaching have on students to improve their performance in solving quadratic equations by the graphical method compare to the conventional approach?
3. What are the views of students on the effect of constructivist approach on SHS 2 students?

To determine the extent of which the use of constructivist approach of teaching improves students' level of understanding of solving quadratic equations by the graphical method, research question two was formulated in hypothesis form to guide this study. They were tested at 0.05 alpha levels of significance:

$\boldsymbol{H_O}$: there is no significant difference in student's performance in pre-test and post-test scores in solving quadratic equations by the graphical method.

$\boldsymbol{H_1}$: there is a significant difference in student's performance in pre-test and post-test scores in solving quadratic equation by the graphical method.

1.6 Significance of the Study

The poor performance of students now a day has become a great concern to all stake holders, teachers, parent and the government. This research looks at the effect of using constructivist teaching approach to enhance students' performance in solving quadratic equations by the graphical method.

The results of this study should highlight some of the shortcomings existing in the teaching and learning of mathematics particularly solving quadratic equations by the graphical method and would serve as a guide for teachers to vary their teaching methodology to enable students to understand the concept "solving quadratic equations by the graphical method" better.

The society and the general public expect that high school graduates to be able to apply mathematics to real-life situations and recognize different situations. As a result, the students would be beneficial not only to himself/herself but also to the community in which they live. Mathematics education can give students adequate preparation to be able to fit into the society.

The researcher hopes that the findings of this research would encourage and sustain students' interest in learning mathematics and inspire slow learners to improve upon their learning abilities and also go a long way to assist and guide fellow researchers, supervisors/heads of departments, headmasters and policy makers in mathematics education in drawing up the curriculum and syllabus.

Again, the outcome of the study is expected to benefit interested groups like mathematics teachers, students and the society at large. This may encourage students to search and learn for themselves as they are exposed to the constructivist approach of teaching and learning. This could help to overcome the difficulties mathematics teachers encounter when teaching the topic solving quadratic equations by the graphical methods in the SHS mathematics syllables. The study is also to ensure that senior high school students do not become handicapped when there is the need to apply the concept in other area of study.

1.7 Limitation

Financial constraints restricted the researcher from involving other schools in the district for the study. The findings of this study would not be generalized to all Senior High School (SHS) students in Gomoa East District, as the respondents involved were only the second year General Arts two 'A' class (2GA2A) and two 'B' class (2GA2B) Students of Potsin, T.I Ahmadiyya Senior High in the Central Region. This group of students was selected because the problem was detected within the year group. The sample size taken was very small thus fifty-five (55) in relation to the entire population due to limitation in teaching materials and resources. Sampling some of the students from the various classes to participate might have motivated them positively but the researcher restricted to only two class as a result of the limited time at the researcher's disposal within which the study is to be conducted. This placed a limitation on the generalization of the findings of this study.

1.8 Delimitation of the Study

There are so many ways by which quadratic equations can be solved, they are ELSE (Equivalent Simultaneous Linear Equation), Quadratic Factorization, Quadratic

Formula, Graphical Methods and Completing the Squares that are perceived to be difficult to solve but the research is delimited to only Graphical Methods. Teaching techniques such as Behaviorism, Cognitivist, Connectivism and Humanism was also not used but rather, the researcher used Constructivist Teaching Approach to help students to over their difficulties in solving quadratic equations by the graphical method.

1.9 Organization of the Study

The research work has been organized into five chapters.

Chapter one: In this chapter the researcher discussed the introduction, background to the study, discusses the problem of the study that gave rise to the study, including the research questions that guided the research work, purpose of the study, significant of the study, organization of the study, limitation and delimitation.

Chapter Two: This chapter presents review of some related literature and the theoretical perception.

Chapter Three: The chapter deals with the research methodology and describes the research design, population and sampling techniques, the instrument to be used, the validity and the reliability of these instruments, procedure for gathering data, and the statistical tool that has been employed to analyzed the data.

Chapter Four: In this chapter, data collected from the student's pretest posttest and interviews are analyzed and interpreted. The result is used to answer the research questions.

Chapter Five: A summary of the research and the findings made are presented, followed by conclusions, recommendations are made, including suggestions for further research.

CHAPTER 2

LITERATURE REVIEW

2.0 Overview

The literature review focuses on the theoretical framework of the study as well as what other researchers have said on the use of constructivist teaching approach in solving quadratic equations by the graphical method. The literature reviewed includes among other concepts under the following themes:

- Theoretical framework: Constructivist Learning Theory
- Concept Formation of Mathematics
- Functions in the Ghanaian Mathematics Senior High School Curriculum
- Learner's Difficulties in Construction of Graph of Quadratic Functions
- Summary of Literature Review

2.1 Theoretical Framework

The theoretical framework of a study is the structure that can hold or support a theory of a research study. Swanson (2013). It serves as the foundation or basis upon which research is constructed. The theoretical framework, thus, establishes links between the theoretical and practical components of the research under consideration. Obviously, it describes a collection of theories that support research (Ofori & Dampson, 2011). Therefore, the theory that supports this study is Constructivist Theory of Teaching and Learning. The researcher deemed it appropriate to base the study on this principle because it is a theory on which many research works have been based, a theory recognized to be effective in helping learners, and is embraced by most educators.

According to Duffy and Cunningham (1996), the theories of learning that hold the greatest influence today are those based on Constructivist principles. This principle is based around the idea that learners are active participants in their learning process; knowledge is constructed based on learner's prior experiences. The idea that students actively construct knowledge is central to constructivism. Students build their new experiences on top of their current foundation of understanding. As stated by Woolfolk (1993) "learning is active mental work, not passive reception of teaching

Unlike the traditional methods, which is characterized by rote learning, memorization and drills, students usually memorize what their teachers say, constructivism allows students to bring their own fresh ideas to the table for discussion, with their ideas being recognized and improved through a variety of teaching and learning techniques that actively engage them. Furthermore, constructivism allows knowledge to be acquired through interactions between teachers and students, in which the teacher assists the students in constructing their own experience and knowledge rather than imposing knowledge on them. In this case, acquiring mathematical knowledge in the classroom becomes learner-centered activity rather than being a teacher-centered activity.

Teacher's instructional method of teaching mathematics, as well as other factors such as student's poor performances in mathematics and negative attitudes toward mathematics has prompted a call by most mathematics educators for instructional reform in mathematics education. These instructional reforms that most mathematics educators desire for can be best understood from the Constructivist's perspective.

In this theoretical framework, learning as viewed by (Howe & Jones,1993, p. 8-9) is a process of self-regulated transformation of old knowledge to new knowledge, a process that requires both action and reflection on the part of the learner. The research of cognitive psychologists and science educators over the past decade has shown that what children learn greatly depends on learner's already existing knowledge and understanding grow slowly, with each new bit of information having to be fitted into what was already there.

The constructivist theory is based on the works of Piaget, Vygotsky, Bruner, and John Dewey philosophy. The concept behind constructivism is that children build knowledge from their own experiences and mode of thought. Teachers who use constructivist methodology believe that true understanding occurs only when children fully participate in the development of their own knowledge, which occurs on moral, cognitive, mental, and social levels, a variety of differing views are found within constructivism, as the concept has been defined differently by various researchers and authors (Woolfolk et al., 2008). For example,

Draper (2002) defines constructivism as “the philosophy, or belief, that learners create their own knowledge based on interactions with their environment including their interactions with other people” (p. 522). That is to say that, in constructivist teaching-learning theory, learning occurs through experimental, real-life experiences that construct and conditionalize knowledge over time. The learners are active participants through interaction with others. They use their experiences or prior experiences to understand new information. The teacher in the constructivist teaching-learning theory is a facilitator who provides scaffolding to promote learning. Scaffolding is a key feature of effective teaching, where the adult continually adjusts the level of his or her help in response to the learner's level of performance. In the classroom, scaffolding can include modeling a skill, providing hints or cues, and adapting material or activity (Copple & Bredekamp, 2009).

Gatlin (1998) and Applefield et al. (2001) described constructivism as an epistemological view of knowledge formation emphasizing construction rather than transmission and recording of information given by others. Knowledge is not self-contained and is not comprised of accumulated 'truths'. Individuals construct their own meaning based on their own experiences; thus, all knowledge must be tentative, personal, and subjective.

Similarly, Richardson, (1999) sees Constructivism as programs that are student-centered and are based on a theory of learning that focuses on how students develop understandings. Students are involved in the learning process, which distinguishes the constructivist approach from the traditional (direct instruction) approach. Teachers who use constructivist pedagogy create lessons that encourage children to engage in self-directed problem solving rather than direct instruction. "Most constructivists would agree that the transmission approach to teaching, usually delivered through lecture or direct instruction, promotes neither the interaction between prior and new knowledge nor the conversations that are necessary for intense involvement in ideas, connections between and among ideas, and the development of deep and broad understanding" (Richardson, 1999).

Constructivism is also a philosophical explanation for the nature of knowledge where students connect prior knowledge to current activities. Constructivism, as an epistemology, asserts that, knowledge is formed by the knower from existing beliefs and experiences. Students participate in hands-on and cooperative learning activities, as well as student-centered lessons that capitalize on children's natural curiosity about the world. Teachers assess students' prior misconceptions in the classroom and attempt to correct them through this identification.

McNichols (2000), also holds that constructivism is a theory about knowledge and learning. This theory incorporates the ideas that:

- The learner is responsible for his or her own knowledge acquisition.

- Meaning, which is represented as knowledge, is based totally internally in the learner
- Knowledge is gained through the learner's experiences and values, which are shaped by reflection, inquiry, and cognitive dissonance.
- Learning is an internal process that is aided by the mutual negotiation of ideas.

Thus, constructivist pedagogy does not direct teachers in what and how to teach, but urges instructors to facilitate teaching and learning by providing a conducive teaching and learning environment for such in the classroom. Learning developed from the work of Vygotsky (1978) proposes that, all learning necessarily builds on prior learning (schema) and teaching must therefore account for the attitudes, previous learning and associations learners bring to the learning task.

A Schema is a concept of new information being fitted into a knowledge paradigm that is already there. According to Hyde (1996) schema is a general knowledge framework that a person has about a particular topic. A schema organizes and guides perception. As people experience the world and reflect upon those experiences, they build their own representations and incorporate new information into their pre-existing knowledge (schemas). It is due to this schema concept that true higher level comprehension can occur, not simply memorization. When everything connects in the mind, memorization is no longer required as the primary mode of learning. Applefield et al. (2001), argued that, regardless of the level of sophistication of a student's existing schema, each student existing schema, or knowledge structure, will have a profound impact on what is learned and whether or not real learning (as defined as conceptual change) occurs. Schema also entails placing items in their right context. Student's development and motivation to learn are enhanced in environments where they may interact with their peers, teachers, toys, or instructional materials. Students employ their senses to perceive the world while they play; they feel, see, hear, and occasionally taste the world and the items with which they are playing. When learning is dynamic, new knowledge is organized into the appropriate schema or context for the situation.

Research has shown that too much teacher-directed instruction has either negative effects at worst or neutral effects at best on children's development (Meade, 1999). What is learned tends to be context-bound and tied into the situation in which it is learned (Lave & Wenger, 1991).

In general, constructivist theory of teaching and learning provides teachers and educators with an understanding of how students learn; they are underpinned by two main principles: "that learners are active in constructing their own knowledge and that social interactions are important to knowledge construction (Bruning et al. 2004). Through experience, interaction, and active involvement with the learning environment, the individual learner constructs and gains new knowledge. Learners create knowledge by building on previously constructed knowledge and students can better grasp the concepts and move from simply knowing the material to understanding it (Ward 2001). According to constructivist theory, it is believed that students' progress from the known to the unknown and having a strong foundation in a particular concept is critical, as the development of new knowledge is dependent on what is already known.

2.1.1 Principles of constructivist teaching and learning

Constructivism is 'an approach to learning that holds that, people actively construct or make their own knowledge and that reality is determined by the experiences of the learner' (Elliott et al., 2000, p. 256). In elaborating constructivists' ideas, constructivist believes in personal construction of meaning by the learner through experience, and that meaning is influenced by the interaction of prior knowledge and new events. Teachers in the constructivist learning environments implement the following principles:

1. **Knowledge is Constructed Rather than Innate, or Passively Absorbed**

Constructivist's central idea is that human learning is constructed, that learners build new knowledge upon the foundation of past knowledge. According to Phillip (1995), this prior knowledge influences what new or modified knowledge an individual will construct from new learning experiences

2. **Learning is an Active Process**

Learning is an active rather than a passive process. The passive perspective of teaching views the learner as 'an empty vessel' to be filled with knowledge, whereas constructivism states that learners construct meaning only via active engagement with the world (such as experiments or real-world problem solving).

3. **All Knowledge is Socially Constructed**

Learning is a social activity we do together, by interacting with each other. Vygotsky (1978) believed that community plays a central role in the process of making meaning. For the researcher, the environment in which students grow up has an impact on how they think and what they think about in their learning process. As a result, all teaching and learning is a matter of sharing and negotiating socially constituted knowledge. Vygotsky (1978) continues to assert that cognitive growth emerges from social interactions from guided learning within the zone of proximal development as children and their partner's co-construct their own knowledge.

4. **All Knowledge is Personal**

Each individual learner has a distinctive point of view, based on existing knowledge and values.

This means that same lesson, teaching or activity may result in different learning by each pupil, as his or her subjective interpretations differ. Fox (2001) argues that:

a. That although individuals have their own personal history of learning, nevertheless they can share in common knowledge, and
b. that although education is a social process, powerfully influenced by cultural factors, nevertheless cultures are made up of sub- cultures, even to the point of being composed of sub-cultures of one. Cultures and their knowledge base are constantly in a process of change and the knowledge stored by individuals is not a rigid copy of some socially constructed template. In learning a culture, each child changes that culture.

5. **Learning Exist in the Mind of the Learner**

The constructivist theory posits that knowledge can only exist within the human mind, and that it does not have to match any real-world reality (Driscoll, 2000).

Learners will be continually attempting to construct their own mental model of the real world from their perceptions of that world. As they perceive each new experience, learners will continually update their own mental models to reflect the new knowledge, and will, therefore, construct their own version of reality.

2.1.2 Characteristics of constructivist teaching and conventional ideas about teaching

Constructivist teaching and learning is stands in contrast to traditional teaching practice in the Ghanaian Classroom. The primary goal of constructivist teaching is to assist students to use their experiences or prior experiences to understand new information. A constructivist classroom is a student-centered classroom. Teachers in the constructivist classroom create collaborative problem-solving environment where students become active participants in their own learning. They use guided discovery, discussion on thoughts and ideas as well as activities to help student learn. The teacher makes sure he/she understands the students' preexisting conceptions, and guides the activity to address them and then build on them (Oliver, 2000).

Teachers in the constructivist classroom constantly encourage their students to assess how the activity is helping them gain the understanding of the concept. As they question themselves and their strategies, students in the constructivist classroom ideally become "expert learners". This serves as a motivation that keeps them learning. When students continually reflect on their experience, they find their ideas becoming complex. The students develop increasingly strong ability to integrate new information. One of the teacher's main role is to encourage this learning and reflection process (Donlevy & Donlevy, 2000).

Learning in the constructivist classroom can be attributed to a number of different teaching practices where students are encouraged to use active techniques to create more knowledge, and then to reflect on and discuss what they are doing with their pairs and how their understanding is changing (Donlevy & Donlevy, 2000).

In the constructivist classroom, learning activities are characterized by active engagement, inquiry, problem solving, and collaboration with others. Students often work in groups, learn social skills, and support each other's opinion and inputs. According to Vygotsky, children develop in social or group settings. Instead of working alone, children benefit when the teacher serves as a guide, facilitator, and co-explorer who encourage learners to question, challenge, and formulate their own ideas, opinions, and to work in groups to discuss issues and challenges that are rooted in real life situations. Students learn best in situations where they dialog with each other about problems (Applefield et al., 2001).

Tam (2000) identified four basic characteristics of constructivist learning environments, which must be considered when implementing constructivist teaching strategies:

- Knowledge will be shared between teachers and students.
- Teachers and students will share authority.
- The teacher's role is one of a facilitator or guide.
- Learning groups will consist of small numbers of heterogeneous students

Ugwuegbulam and Nwebo (2014) posed the following as activities in the constructivists' classroom:

- **Experimentation**: In this case, the students are given an experiment to conduct on their own individually before coming together as a class to discuss their findings

- **Research projects:** students conduct assigned research on their own time and then present their findings to the rest of the class.
- **Field trips:** The planning and execution of field trips is one of the activities constructivists engage in in their classrooms. Students are allowed to put the concepts and ideas discussed in class in a real-world context. At the end of the field trip, they are expected to write reports and then share their experiences with the rest of the class.
- **Films:** Teachers in the constructivist classroom use this method to add another sense to the learning experience by providing visual context for what is being learned.
- **Discussion in class:** This technique runs through all of the other techniques listed above. It is one of the most significant differences in the constructivist-teaching model

Teacher-centered, text-centered, and skills-oriented approaches to mathematics instructions are replaced by more student-centered approaches that emphasize understanding processes from a constructivist perspective, where the student is seen as the meaning-maker. Instead of treating mathematics as a body of knowledge, skills, and strategies to be memorized. Constructivist teaching approach treats it as of knowledge, skills, and strategies that must be constructed by the learner from experiences and interactions within the social context of the classroom. The focus of a constructivist student-centered approach is on the students' learning rather than of the teachers teaching.

In contrast, a traditional perspective focuses more on teacher - centered approach. This learning process is constantly influenced by the teacher's guidance. In this case, the students are listening while the teacher gives instructions; the students become passive receivers of the information presented. When using this method, students do not have the opportunity to express themselves. The following are the methods used in teaching in the traditional classroom teaching perspective, and they are as follows:

- **Lectures and Direct Instruction**: It is a classroom-based method where the lecturer or teacher gives direct instructions. This means that the teacher stands in front of the classroom talk all of the time and presents the information. Students are viewed as "empty vessels" who passively receive knowledge from their teachers through lectures and direct instruction, with an end goal of positive results from testing and assessment. In this style, teaching and assessment are viewed as two separate entities: student learning is measured through objectively scored test and assessments.
- **Listening and Observations:** This method includes student's learning process through the teacher, students listen to the teacher and the teacher expects them to say everything they explain in the classroom.

Applefield, Hubert and Moalem (2001) compared traditional teaching methods to constructivist-based teaching methods, which involves isolating the basic skills, teaching occurs by separating and building these incrementally before tackling higher order tasks.

Although cognitive information processing views often lead to similar instructional practices, this is essentially an objectivist and behavioral approach to instruction (teaching method). Teachers provide feedback orally or on the chalkboard, and students are expected to follow their teachers' instructions. Students are not encouraged to talk to one another or interact with one another. This teacher- centered method of teaching also assumes that all students have the same level of background knowledge in the subject matter and are able to absorb the material at the same pace (Lord, 1999).

According to Fredua-Kwarteng and Ahia (2015), the learning culture of mathematics in Ghanaian schools are such that, students learn mathematics by listening to their teacher and copying from the chalkboard. As a result, rather than mathematics by recalling of facts, theorems, or formulas. Students rarely inquire about the logic or philosophy behind the mathematical principles, facts, or formulas.

As a result, conventional methods of teaching and learning mathematics do not motivate students, nor do they target the development of understanding or support student-centered learning. Students are not involved in solving problems that have a variety of possible solutions. When acquiring an understanding of constructivist teaching and learning, it is vital to generate awareness in terms of constructivist pedagogies and conventional pedagogies. Table 1 below highlights the various aspects as stated as follows:

Table 2.1: Distinctions between the conventional classroom environment and the constructivist classroom environment

Approaches	Traditional Classroom Environment	Constructivist Classroom Environment
Instructional methods	Instructional activities are teacher-centered	Instructional activities are learner-centered
Collaboration	Repetition is the foundation of learning. Learners are required to be attentive and disciplined to acquire an understanding of the content that is set in the discipline	Learning is interactive, with the student building on what they already know
Responsibility for Learning	Teachers disseminate information to students; students are knowledge recipients (passive learning)	Teachers engage in dialogue with students, assisting them in developing their own knowledge (active learning).
Role of Teacher	The teacher's role is directive and based on authority.	The teacher's role is collaborative and based on negotiation.
Working of Students	Students primarily work alone (competitive).	Students primarily work in groups (cooperative).
Teaching aid	The majority of the materials are textbooks and workbooks.	Teachers engage in dialogue with students, assisting them in the construction of their own knowledge
Classroom Assessment	Testing and correct answers are used for evaluation.	Student work, observations, and points of view, as well as tests, are all part of the assessment process. The process is just as important as the product.

2.1.3 Effects of constructivism on student's learning

The employment of a constructivist educational approach has a direct impact on students learning. Students in a constructivist classroom are active participants in the process of knowledge construction and its dissemination. They take part in the teaching-learning process and take ownership of their own learning by giving it meaning in their own settings. Constructivism allows students to study cooperatively and collaboratively.

A study was conducted by Santmire, Giraud and Grosskopf (1999) and compared learning achievement of two groups of elementary school students. The researchers discovered that students who learnt using a social-constructivist approach to education and completed a standardized test scored higher than those who were taught in a conventional classroom setting. As a result of their involvement in such projects, the students' academic achievement improved as well.

Constructivism involves students and they participate actively in the teaching and learning process through different activities. Pratton and Hales (1986) studied the influence of such participation of students on their learning achievement. According to the findings, students who actively participated in the teaching learning process had higher mean achievement than those who attended regular classes. According to the study, students spent more time on activities that required them to think, respond, and check their knowledge. As a result, active student participation (constructivism) has been confirmed as an effective instructional strategy for generating and maintaining motivation and passion for knowledge production.

2.1.4 Research on the effectiveness of constructivist instructional approach

Tellez (2007) reviewed major reform efforts in curriculum and pedagogy to establish that "the importance of constructivism in educational theory and research cannot be under estimated". Several studies in science-related disciplines support the constructivist approach (Phillips, 1995; Cobb, 1996; Fox, 2001; Dangel, 2011), have all referenced previous studies advocating for constructivist instruction in science-related fields. This study summarized previous research on constructivist teaching methods. The review of the articles included a basic summary, methods, results, and discussions of the research findings of the numerous studies works.

Research performed by Guthrie, Taboada, and Humenick (2004) compared three instructional methods for 3rd grade reading: a traditional approach, a strategies instruction only approach, and an approach with strategies instruction and constructivist motivation techniques including student choices, collaboration, and hands-on activities. The constructivist resulted in better student reading comprehension, cognitive strategies and motivation. Kim (2005) found that using constructivist teaching methods for the 6th Graders resulted in better learner achievement than traditional teaching methods. The Kim's (2005) study also found that learners preferred constructivist methods over traditional ones. However, Kim (2005) did not find any difference in student self-concept or learning strategies between those taught by constructivist and those taught in traditional methods.

Baser (2006), found that constructivist instruction fosters conceptual change more than traditional instruction. The pretest-posttest experimental design was used in Baser's study, which included thirty-eight (38) learners who were given constructivist education and thirty-six (36) who were given traditional instruction. Both groups got the same instructions, but the experimental group was subjected to conditions that required them to modify their minds. Baser discovered that when both groups were evaluated and their performance was compared, the conceptual change group outperformed the traditional group.

In a comparative study by Tynjala (1998) found similar results of the learning outcomes of educational psychology students studied with traditional learning task with examinations and students studied with constructivist-learning tasks without examination. The study was conducted using the pretest-posttest experimental design, involving thirty-eight (38) learners exposed to constructivist instruction. The Constructivist group students were given assignments that require transforming knowledge, activating previous knowledge, comparing and criticizing different theories. Students discussed their assignments in groups and were made to write an essay. To provide research material they were administered a control group's exam but they were not graded. Traditional group students were instructed by traditional methods. They attended classes, studied the textbook on their own and had an examination. Tynjala (1998) found that students in the constructivist group acquired an ability to apply knowledge and developed their thinking and communication skills.

Doğru and Kalender (2007) conducted a study on students' retention by comparing science classrooms using traditional teacher-centered approaches to those using student-centered constructivist methods. In the Pre- test of learner performance, which was administered immediately after the intervention, Doğru and Kalender (2007) found out that there was no significant difference between traditional and constructivist methods. However, in the post-test assessment, which was administered after 15 days, students thought using constructivist methods showed better retention of knowledge than students thought through the comparative traditional methods. Bhutto (2003) also investigated the effect of teaching of algebra through social constructivist approach on seventh-Graders' learning outcomes in Sindh in Pakistan. Bhutto divided learners into two groups the experimental group and the control group. The results of the investigation indicated that, the experimental group that was instructed by the social constructivist approach excelled in achieving statistically significant learning outcomes than the control group who were instructed traditionally

Origa (2000) investigated the impact of constructivism theory in learning geometry among girls in Kenyan secondary schools. The aim of the study was to find out if differences exist in performance of girls who learned geometry through constructivist method and those who learned through other instructional methods. The results of the study indicated that the girls who were instructed by constructivist instruction attained better scores in post-test compared to girls who learned through other instructional methods. Miheso-O 'Conner (2002) conducted a study on the relationship between interactive and conventional teaching methods on acquisition of high order thinking skills in learning mathematics among secondary school students in Nairobi. The study found that interactive methods of teaching are more effective and yield better results at higher order skills learning than conventional method of teaching. The interactive teaching methods discussed by Miheso-OConner (2002) are essentially constructivist instruction learning methods.

In another study conducted by Khalid (2012), it was revealed that students in a constructivist classroom not only learned more, but also had a greater rate of competency than students in a typical or conventional learning setting. Students in the constructivist group expressed a high degree of pleasure and increased participation. Students were more likely to provide answers and ask questions of the instructor to clarify content, and group discussions resulted in the introduction of many new points. The study findings demonstrated that constructivist teaching is far better as compared to conventional method.

2.1.5 Constructivist Approach of Teaching Quadratic Function in the Mathematics Classroom

In the philosophy of mathematics education, constructivism is derived from Piaget's theory of cognitive development (i.e., how thinking and knowledge develop with age). According to the constructivist theory of learning, learners arrive at making meaning of information by actively selecting and cumulatively constructing their own knowledge through both individual and social activities. As a result, the learner brings an accumulation of assumptions, motives, intentions, and prior knowledge about the teaching and learning situation and determines the course and quality of learning that may occur. This view of learning places a lot of emphasis on understanding instead of memorizing and reproducing information (Tynjala, 1998) in every learning situation.

According to Simon and Schiffer, (1993), the constructivist view of learning is in sharp contrast to the notion implicit in the traditional approach that learners come to understand by taking clear explanation. From a constructivist perspective, teaching is not about transmitting knowledge but about assisting learners to actively constructing their own knowledge by assigning tasks that facilitate this process. The assumptions of constructivists about how learners learn change the assumptions about what kinds of educator actions or behaviors are desirable.

Those who see teaching as the transmission of knowledge would adhere to a teaching-by-imposition model, while those who see teaching as the facilitation of knowledge construction would adhere to a teaching-by-negotiation model. The role of educators in initiating and guiding mathematical negotiations is a highly complex one that includes highlighting conflicts between alternative interpretations. Simon and Schiffer (1993) stated that, the educators' role in initiating and guiding mathematical negotiations is a highly complex activity that includes:

1. highlighting conflicts between alterative interpretations or solutions
2. helping learners to develop productive small-group collaborative relationships
3. facilitating mathematical dialogue between learners
4. implicitly legitimizing selected aspects of contributions to discussion in light of their potential fruitfulness for further mathematical constructions
5. re-describing learners' explanations in more sophisticated terms that are nonetheless comprehensible to learners
6. guiding the development of taken-to-be shared interpretations when particular representational systems are established.

With the constructivist principle in mind, Wood (1995) suggested four principles educators should follow to engage learners in meaningful learning.

- Provide instructional situations that elicit subject appropriate activities.
- View learners' conceptions from their (the learners') perspectives.
- See errors as reflecting their learners' current level of development.
- Recognize that substantive learning occurs in periods of conflict, surprise over periods of time, and through social interaction.

The effect of using constructivist approach of teaching excites and sustain the interest of learners, ensures practical work, enables learners to acquire skills and promotes acquisition of first-hand information. Having said that, it is clear that incorporating constructivism into the quadratic function mathematics classroom will go a long way toward resolving some of the issues that impede learners' understanding of quadratic functions especially solving quadratic equations by the graphical method. Active learning processes was advocated in the Core Mathematics Curriculum for Senior High School 2007 and Mathematics Common Core Programme Curriculum February 2020, that active learning processes should replace traditional passive learning.

2.1.6 Conventional way of Teaching Quadratic Function in the Mathematics Classroom

In the conventional mathematics classroom, learning is done with the teacher's guidance all the time. In this case, students listen while teacher gives instructions. Students do not have the chance of expressing their thoughts when using this kind of method. The teacher is seen as knowing everything and that the learner is almost blank (Onwuka, 1985). As a result, it is the teacher's responsibility to pass on his knowledge to his students. That is, the teacher imparts knowledge to the students, who are typically assumed ignorant and illiterate. The conventional classroom was viewed as a silent working environment where children were passive listeners and where narrow perspectives and misconceptions were formed.

The lesson does not allow for experiences where children are able to discover, invent or apply mathematics to problems that are meaningful to them (Cangelosi, 1996). A good mathematics classroom with meaningful teaching and learning provides a powerful means of communication between the teacher and students or between the students themselves, whereas the conventional mathematics classroom is ironically a place where children's opinions are never heard.

This teaching approach does not take much account of differences between pupils in a particular class with respect to their speed of learning or their previous knowledge (Bell, 1973). This method of mathematics instruction includes whole-class instruction, recitation, and individual seatwork. Conventional approach success, on the other hand, does not provide a thorough understanding of mathematical concepts because in the classroom more time is spent on routine computational skills.

In the traditional method of instruction, the quadratic function is introduced by writing its standard form $y = ax^2 + bc + c$. Students are given quadratic functions in standard form, for which they are required to complete the table of values and subsequently plot the graph using the table. The students are not given enough activities to enable them investigate the properties of the quadratic functions but are required to solve problems using the graph. This includes line of symmetry, maximum and minimum value and value for which they occur, maximum and minimum points, the roots (zeros) of the given equation and many more.

According to Leinhardt, Zaslavsky & Stein (1990), students' difficulties in dealing with a function given in graphical form or connecting functions with their graph are as a result of traditional instructional method.

2.2 Conceptual Formation of Mathematics

Critical thinking is best developed through good instructional method of teaching mathematics. Actually, the foundation of science and technology is mathematics. The learning of mathematics is based on progressive building of concept which is independent, Skemp (1986: 30) as sited in Nabie (2002,2004) proposed two guiding principles for helping children to learn mathematics concepts. The principles state that:

- Concept of higher order than those people already have cannot be communicated to them by a definition, but only by arranging for them to encounter a suitable collection of examples.

- Since in mathematics these examples are almost invariable other concepts, it must first be ensured that these are already formed in the mind of the learner.

Similarly, Polya (1981) also pointed out that mathematics is useful to the individual in mathematics that has been developed through pupil's involvement. This suggest that knowledge is not taught by teachers acting as a transmitter or is it leant by learners acting as passive receiver of information. Active learning takes place when the individual is involved in the learning process.

Holbrook (1961) revealed that student have difficulty in solving mathematical problems due to the lack of the basis of the concept as well as inconsistent practices. He suggested that more exercises should be given to the children for the more frequently a learning situation or experience is repeated, the more permanent the learning. That is practice strengthens competence and lack of practice weakens skills.

Furthermore, Ball (1991) also suggested that the subject matter knowledge for teaching included knowledge of mathematics and knowledge about mathematics. He argued that to teach mathematics effectively, the individual's knowledge of mathematics must be characterized by a clear conceptual understanding of the principles and meaning underlying mathematical procedures. Systematic build-up of concepts makes learning easier. To ensure coherent understanding of mathematical concepts there should be provision for backtracking or remedial teaching especially at the school level.

According to Brain (1995) "mathematics is not spectator spent" that is, you can learn mathematics by just reading worked example or watching your instructor work problem. You must however, work similar problems for master.

2.3 Functions in the Ghanaian Mathematics Senior High School Curriculum

The Ministry of Education, Science and Sports (2007) stated that, the concept of function is a fundamental unifying idea in Mathematics. As a result, it is greatly emphasized in the senior secondary school mathematics curricular. The mathematics syllabus of senior high schools (2007) requires that function is to be taught from first year through to the third year. The learners are required to study the various families of functions that include: linear functions, hyperbolic functions, quadratic functions, exponential functions, and trigonometric function. The learners are required to recognize the relationships between variables in terms of numerical, graphical, verbal and symbolic representations and to convert flexibly between these representations (tables, graphs, words and formula). They are also required to generate graphs by means of plotting points and hence generalize the effects of the given parameters (a, b $and.$ c) in the functions. In the process, they identify the characteristics listed below and hence use applicable characteristics to sketch graphs of functions.

- Domain and range
- Intercepts with axes
- Turning points, minimum and maximum value or point
- Shape and equation of the line of symmetry
- Gradient of the curve
- Range of values on which the function is increasing or decreasing;
- The discrete or continuous nature of graph. (The Curriculum Research and Development Division (C.R.D.D) 2007, mathematics core syllabus for Senior High School)

Linear equations, linear relations and quadratic equations are prerequisites topics for graphs of functions. Although there are many families of functions that are required to be studied in the SHS mathematics curriculum, this research was carried out by focusing on the quadratic function.

2.3.1 Meaning and Concept of Quadratic Functions

Function is described as, "A relation in which each element of the domain has one and only one image in the range such that the first coordinate is never repeated. There is only one output for each input, so each element of the domain is mapped to exactly one element in the range" (Burger et al. 2007, p. 45). In other words, for every x value there can only be y value. If there was the coordinate point $(2,5)$ on a function, there could not also be the point $(2,9)$ due to the fact that the input $x - value$ 2 has more than one output that is $y - value$. Quadratic functions are second-order polynomials with a special curve called parabola.

The variables of any quadratic functions have two as the highest power. The quadratic function can be written in different forms but changing the form of the expression of the function does not change the function, the graph or the values in the table (Cooney, Beckmann, & Lloyd, 2010). The quadratic function can be express in the standard form as $f(x) = ax^2 + bx + c$ where $a.b$ *and* c are constants and $a \neq 0$, factored (multiplicative) form as $f(x) = a(x - p)(x - q)$ and vertex (canonical) form as $f(x) = a(x - h)^2$ +k.

- ***The standard form*** ($f\ (x) = a\,x^2 + b\,x\ + c$), with this form, it is easy to identify the end behavior of the function and the values for the coefficients of $\boldsymbol{a, b}$ ***and*** $\boldsymbol{c}$ parameters. The parameter $\boldsymbol{c}$ is the value of y − intercept of the graph of the parabola, the equation $x = \frac{-b}{2a}$ is the line of symmetry and the minimum value is $y = f\left(\frac{-b}{2a}\right)$ or $y = \left(\frac{4ac-b^2}{4a}\right)$. The coordinate of the vertex is $\left[\left(\frac{-b}{2a}\right), f\left(\frac{-b}{2a}\right)\right]$.

- ***The factored form:*** $f(x) = a(x-p)(x-q)$ is the product of two binomials, which are linear factors, and a constant value $\boldsymbol{a}$. The end behavior and zeros ($\boldsymbol{x - intercepts}$) of the function is easily identified. There are only two factors making the degree two. This form is not applicable when the function has no real solutions. The zeros (or roots) of the quadratic function are at $x_1 = p \text{ and } x_2 = q$, thus transforming an expression into factored form is a method for finding the zeros or roots. The line of symmetry and vertex of the corresponding parabola lie halfway between the two roots.
- ***The vertex form***: $f(x) = a(x-h)^2 + k$ this form consists of the square of a binomial which is then multiplied by the constant $\boldsymbol{a}$ and summed with the constant k. With this form, it is easy to identify the vertex (tuning point) of the parabola. The vertex (turning point) of the parabola is at (h, k). The line of symmetry is $x = h$, where $h = \frac{-b}{2a}$ and $k = -\left(\frac{b^2-4ac}{4a^2}\right)$, minimum value is $y = k$ where $k = f(h)$ and occurs when $x = h.$

Each of these forms can be expressed from one form to the other by one of the following methods: Expansion and Simplification of the binomials, Factorization, and Completing the Square.

As shown in figure 2.1 below

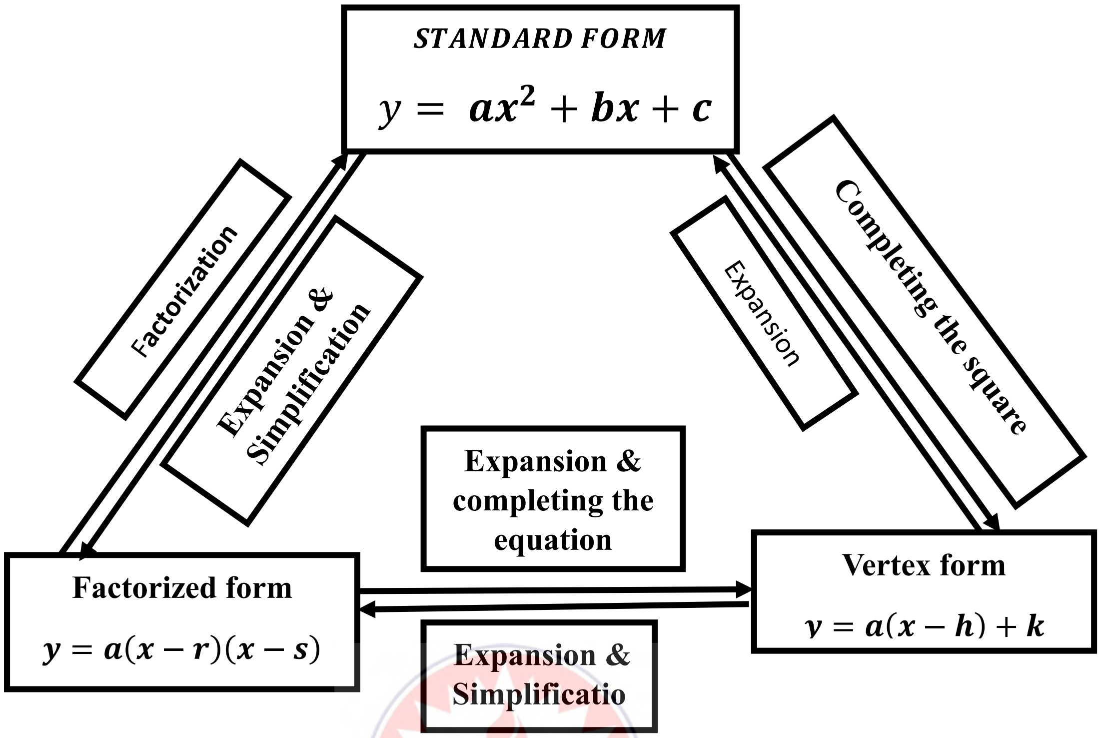


Figure 2.1: The relationship between the three forms of quadratic functions

The graphs of quadratic function are recognized for their ∪ and ∩ $-shaped$ formation that may open up or down depending on the sign of coefficient "a" which is the leading coefficient of the polynomial in standard form. If the sign of coefficient "a" is positive, that is $a > 0$ the quadratic graph opens upwards. In that case, the vertex (turning point) gives the least or minimum value of the function. If the sign of coefficient "a" is negative, that is $a < 0$ the quadratic graph opens downwards. In that case, the vertex gives the greatest or maximum value of the function. Examples of quadratic functions:

$f(x) = 2x^2 - 3x - 9$

$f(x) = -2x^2 + x - 7$

$$f(x) = -\frac{1}{2}x^2 - 3x + 5$$

2.3.2 Quadratic Equation

Quadratic function is called the quadratic equation when the standard form is set to be equal to zero which gives the format $ax^2 + bx + c = 0$. The “solution” of the quadratic equation is obtained when "x" is solved. This solution can be done by using the method of completing the square, quadratic formula, factorization and graphing depending on the question, The “solutions” are called the roots, zeros, or x-intercepts, and are essential when the graph crosses the $x - axis$ of the graph. The quadratic function has the following properties:

I. If $b^2 - 4ac \geq 0$, the quadratic equation has two real solutions or root. The graph crosses the $x - axis$.

II. If $b^2 - 4ac = 0$, the quadratic equation has one solution one real solution or root. The graph touches the $x - axis$ at one point.

III. If $b^2 - 4ac \leq 0$, the quadratic equation has zero or no real solutions. This means that the quadratic is either always above or below $x - axis$. where $b^2 - 4ac$ is called the discriminant, the quantity under the square root sign in the quadratic formula

$$x = -b \pm \frac{\sqrt{b^2 - 4ac}}{2b}$$

2.3.3 The Effects of the Parameters $a, b, and\ c$

Effects of varying "a" the coefficient of x^2

For a quadratic relation $y = ax^2$, varying the value of "a" (leading coefficient) results in a vertical stretch of the graph. That is, the bigger the value of "a" the narrower (steeper) the graph becomes when $a > 1\ or\ a < 1$. Similarly, the smaller the value of "a" the wider (shallower) the graph becomes when $-1 \leq a \leq 1$. This can be seen in the graph of $y = 4x^2$ with

$a = 3,\ 2, 1, 0.5 , -4, -3, -2, -1\ and - 0.5$. As shown in the figure 2.2 below

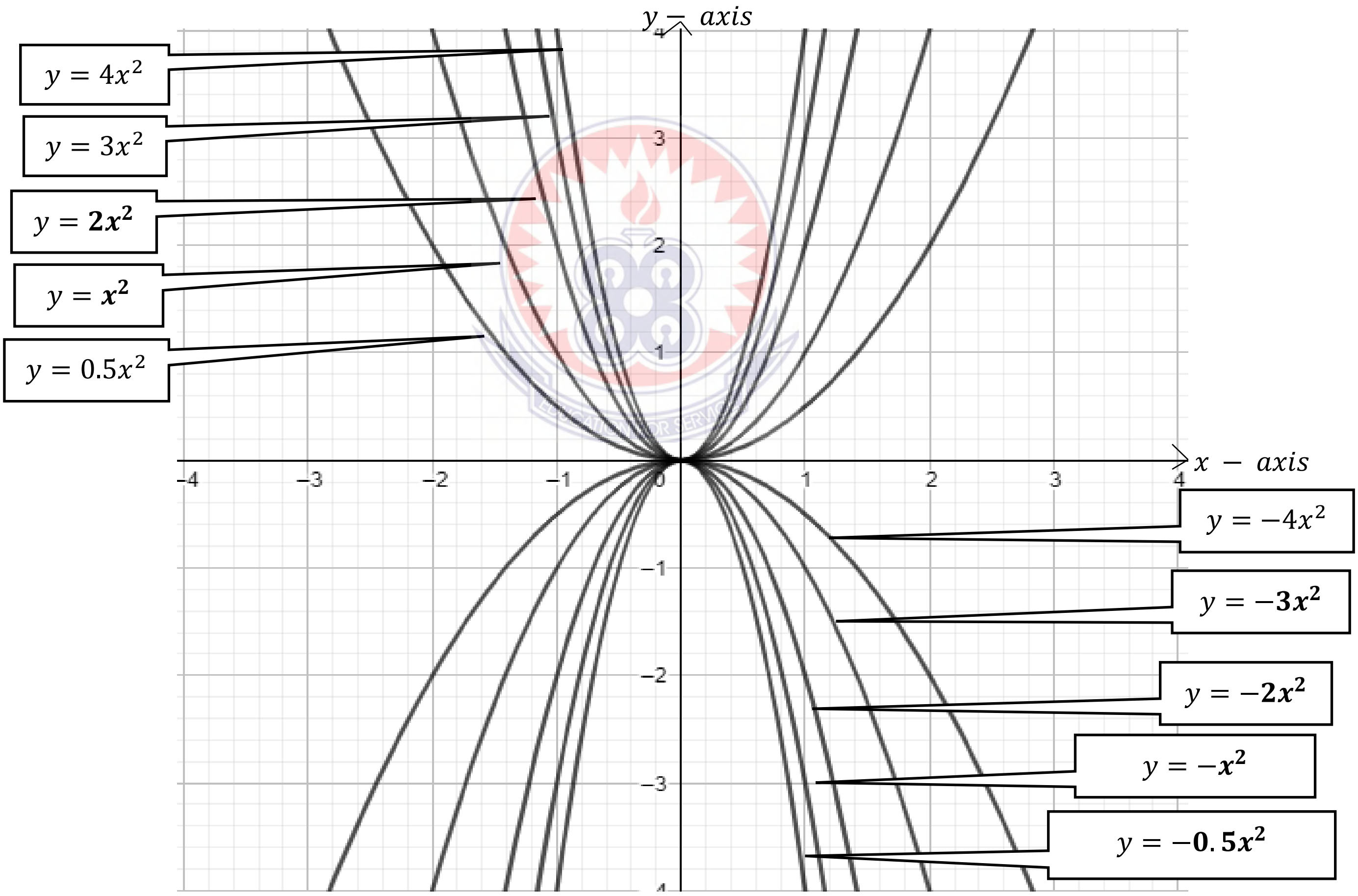


Figure 2.2: The effect of varying the sign "a" to both positive and negative

- **Effects of Varying the Parameter "b" the Coefficient of x .**

For the quadratic function $y = ax^2 + bx + c$, changing the values of b and keeping the values of a and c constant, the graph maintains its shape and direction.

This can be seen in the graph of $y = x^2 + x$ with $b = 2,\ 3, 0.5\ , -1, -2, -3\ and -0.5$ drawn in figure 2.3 below

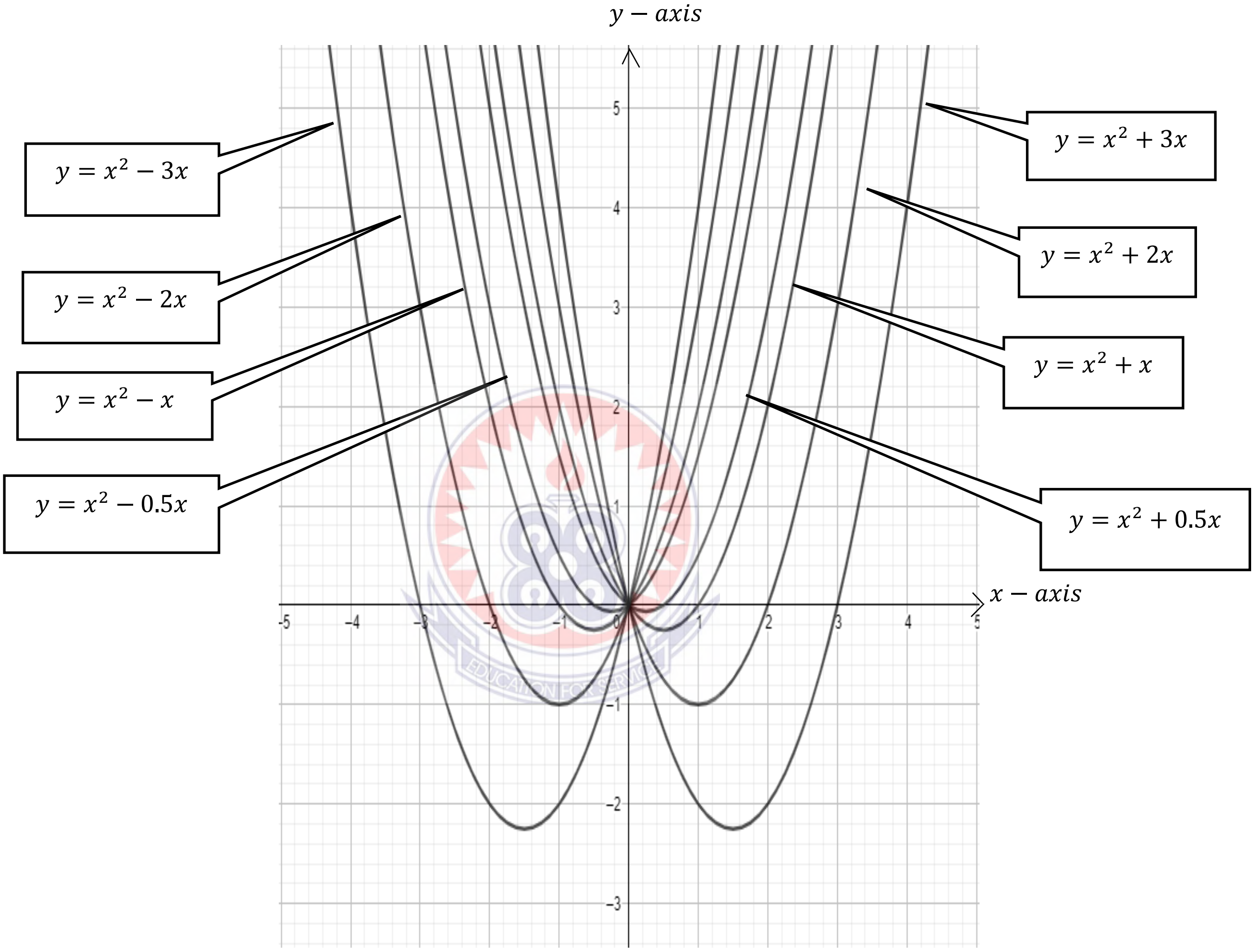


Figure 2.3: The effects of varying the sign "c" to both positive and negative

- **Effect of Varying "c" the $y-intersept.$**

For the quadratic function in the standard form $y = ax^2 + bx + c$, varying the value of "c" changes the width of the parabola results in a vertical translation of the graph of the function by "c" units (up if $c > 0$ and down If $c < 0$). Changing c moves the locus of the vertex along the line $= \frac{-b}{2a}$. The parabola maintains its shape and directions for the range implemented. The line $x = \frac{-b}{2a}$ is the axis of symmetry irrespective of the value of c. This can be seen in the graphs of $y = x^2 + x + 1$, with $c = 2, 3. -1, -2, \text{and} - 3$ drawn in figure 2.4 below

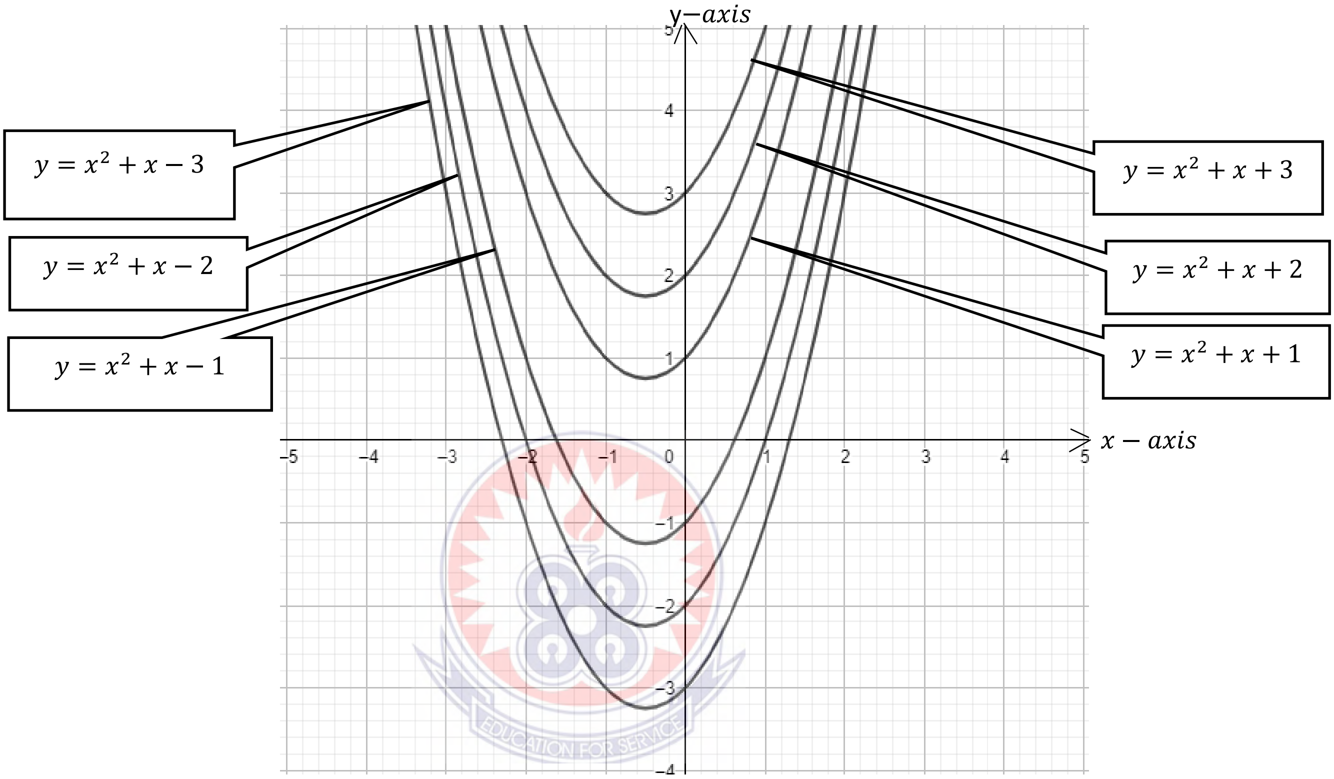


Figure 2.4: The effects of varying the sign "c" to both positive and negative.

2.3.4 Interpretation of the Quadratic Graph

Least or greatest value or point.

The least or greatest value of y occurs at the turning point of the graph of the relation.

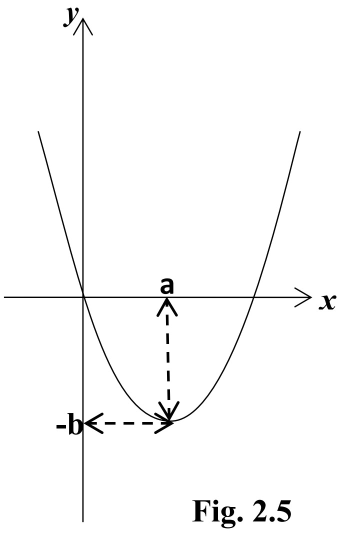


Fig. 2.5

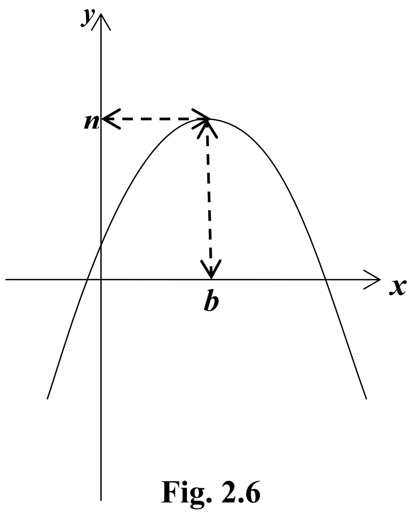


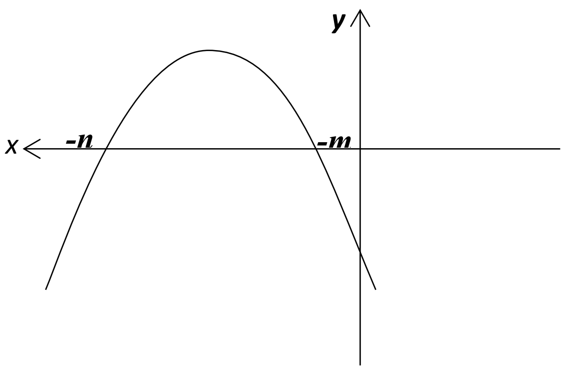
Fig. 2.6

In fig. 2.5 the least value of y is $-b$ and the least point is $(a, -b)$

In fig. 2.6 the greatest value of y is b and the greatest point is (b, n)

The solution sets of the graph ($y = ax^2 + bx + c$)

The solution set of the is where the graph cuts or crosses the $x - axis$



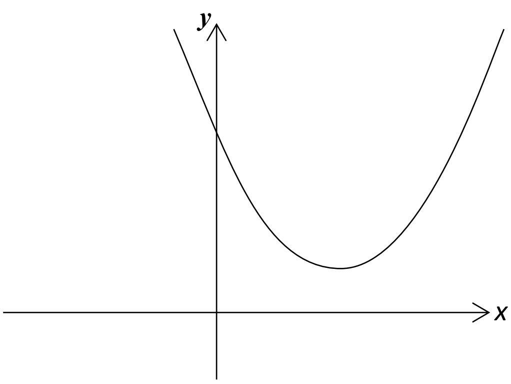


Fig. 2.7

Fig. 2.8

In fig. 2.7 the solution set of the graph $y = ax^2 + bx + c$ is $\{x: x = -m, -n\}$, In fig. 2.8 the graph $y = ax^2 + bx + c$ has no real solution

The equation of the line of symmetry

The line of symmetry passes through the turning point or the vertex. It is parallel to the $y - axis$

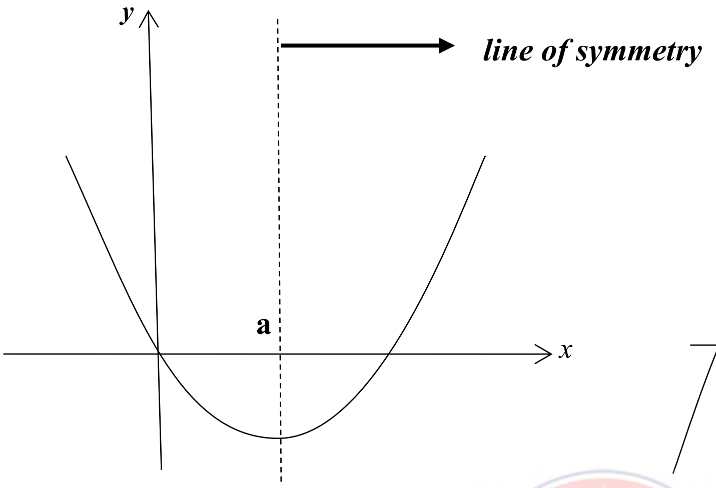


Fig. 2.9

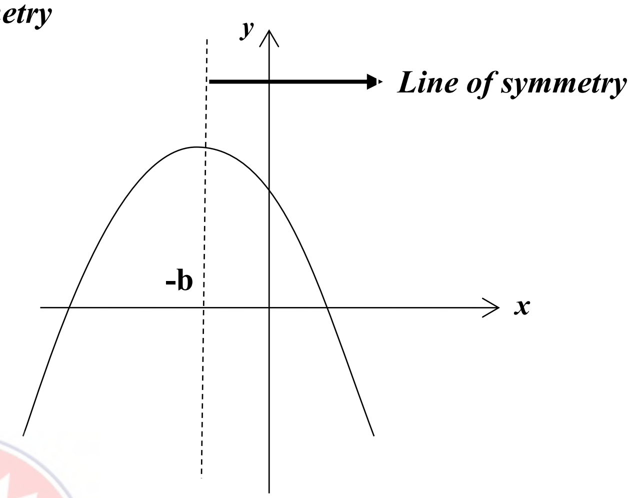


Fig. 2.10

In fig. 2.9 the equation of the line of symmetry is $x = a$.

In fig. 2.10 the equation of the line of symmetry is $x = -b$.

The value of x for which $y \leq 0$ and $y > 0$.

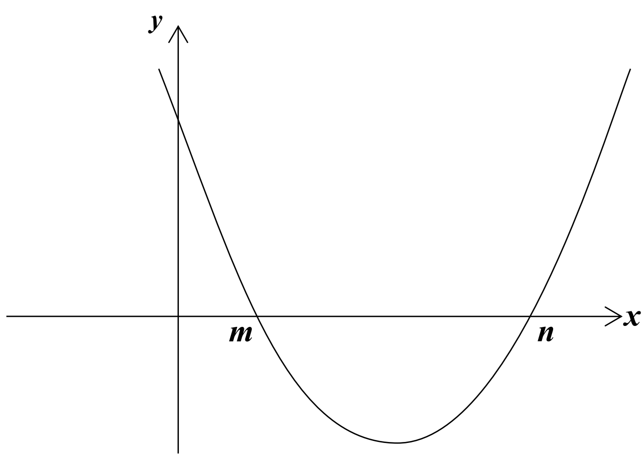


Fig. 2.11

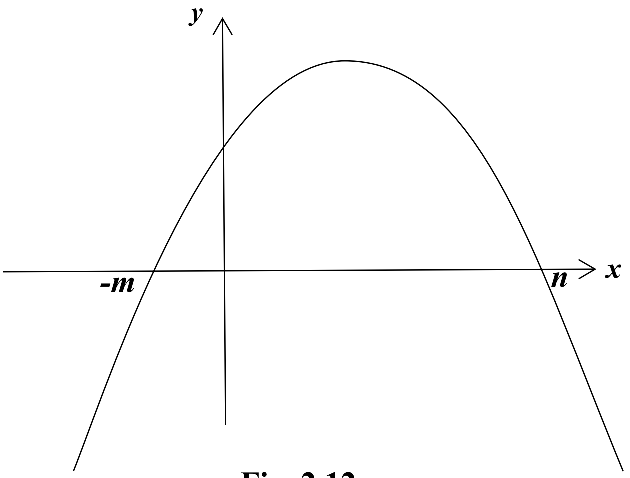


Fig. 2.12

In fig. 2.11: the value of x for which $y \leq 0$ *is* $m \leq x \leq n$

In fig. 2.11: the value of x for which $y > 0$ is $m > x$ or $x > n$

In fig. 2.12: the value of x for which $y < 0$ is $-m > x$ or $x > n$

In fig. 2.12: the value of x for which $y \geq 0$ is $-m \leq x \leq n$

Range of values of x as y increases or decreases

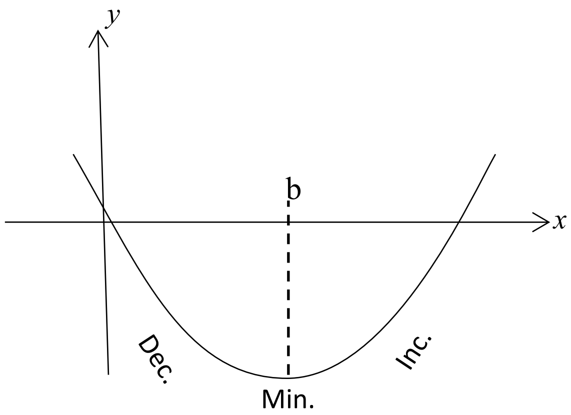


Fig. 2.13

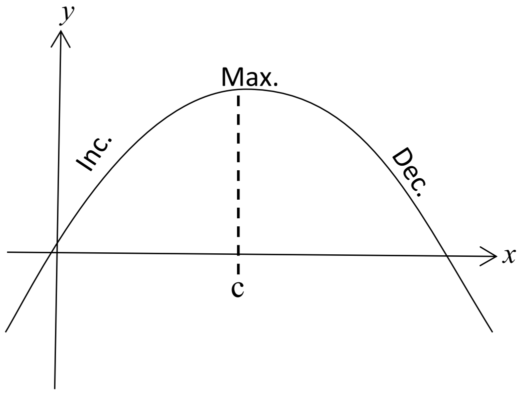


Fig. 2.14

In fig. 2.13: the range of values of x for which y decreases is $x < b$

In fig. 2.13: the range of values of x for which y increases is $x > b$

In fig. 2.14: the range of values of x for which y increases is $x < c$

In fig. 2.14: the range of values of x for which y decreases is $x > c$

To find the gradient of a curve at $x = k$

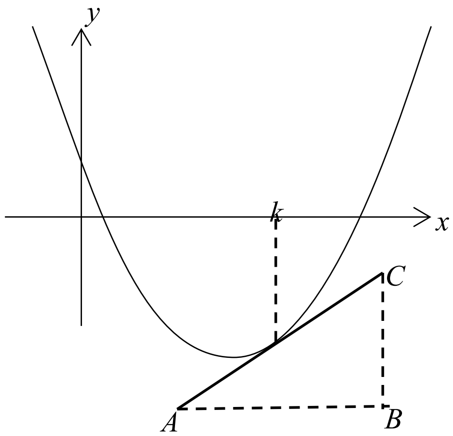


Fig. 2.15

In fig. 2.15: the gradient of the curve at a point is determined as Gradient at $M = \frac{BC}{AB}$

2.4 Learner's Difficulties in Construction of Graph of Quadratic Functions

Zaslavsky (1997) observed numerous misunderstandings pertaining to the study of quadratic functions, the researcher noted that there are several misunderstandings related to how the graph of a quadratic function is perceived, an example is, because of its apparent increase in "steepness," students believe that graphs of quadratic function have vertical asymptotes. Given two intercepts of a quadratic function, students would identify the function as $y = (x - r)(x - s)$. Although this function and the target function share the same roots, they need not be the same, because the 'a' parameter is still not determined given just these two points, Zaslavsky (1997) interpret that, students may over generalize what may be inferred when working with equivalent equations; that is $a(x - r)(x - s) = 0$ and $(x - r)(x - s) = 0$ are equivalent equations because $a \neq 0$ by definition, but this does not imply that $y = a(x - r)(x - s)$ and $y = (x - r)(x - s)$ are the same functions. Vaiyavutjamai, (2009) noted that when working with the vertex form $y = a(x - h)^2 + k$ a student attended to the sign of the "$\boldsymbol{a}$" parameter but not to its value. Zaslavsky (1997) and Vaiyavutjamai (2009) observed that, many students do not consider enough points in attempting to specify graphs of quadratic functions.

There is also evidence that students may not understand the mathematical meaning of procedural rules learned in conjunction with one or more of the algebraic forms presented earlier. The roles of the parameters, particularly the a and b parameters, are not obvious in the standard form, and students may have difficulty distinguishing between the various forms. For example, Eraslan (2008) described how when given the function $y = x^2 + 2x - 3$, a student graphed the parabola so that it "opened up" but located the vertex at the point $(2, -3)$. When asked to express the graph of $y = (x+1)^2 + 4$ as an equation, the same student wrote $y = -x^2 - 1x + 4$. Both of these errors are consistent with conflating the standard and vertex forms. According to Ellis and Grinstead (2008), who focused on students working with the standard form, although the '$\boldsymbol{a}$' parameter is interpreted as influencing the shape of the parabola, students also thought that varying the '$\boldsymbol{a}$' parameter would not change the location of the vertex. This finding could also be explained by a mix-up with the vertex form: changing the a parameter in the vertex form does not change the vertex's location because the '$\boldsymbol{a}$' parameter has a slightly different role in the standard and vertex form. It is easy to see how these forms can be confused: while they have different mathematical interpretations, they share many surface characteristics. If students' schemas for working with quadratic functions are based on memorized rules (e.g., "If 'a'is negative, the graph opens down'') without mathematical meaning, then it might be expected that these confusions will occur. Students may not recognize special cases of the quadratic function, for example, believing that the 'c' parameter does not exist when it is equal to zero (Zaslavsky, 1997). When studying quadratic functions, graph translation activities are frequently explored Zaslavsky (1997), Ellis and Grinstead (2008) also noted certain interference with concepts learned about linear functions, for example, most students sometimes attempt to calculate the slope of a parabola when dealing with standard form, they tend to interpret the '$\boldsymbol{a}$' parameter as the slope of the parabola.

Students also have difficulty with interpreting the parameters of quadratic functions. When working with standard form, interpreting the 'c' parameter (the y-intercept) appears to be more straightforward for most students. Students also seem to have a partial understanding of the 'a' parameter, though the roles of the 'a' parameter in the standard form and the vertex forms may be a point of confusion. When students are working with the vertex form, most of them can readily identify the vertex, but many still have difficulty with transforming the graph, even when using this form. The 'a' parameter in the standard form is difficult to understand and difficult to teach, but exploring its role may be worthwhile for helping to make the link between linear and quadratic functions.

The purpose of a graph is not to provide a means to interpret the precise value of bar, line, curve or point. Instead, the purpose is to see the shape of the data either concave up or concave down and from the shape discern meaningful patterns. According to (Zaslavsky, 1997 as cited in Otchere-Larbi, 2009), research has revealed that most student see the graph of quadratic function as pictures rather than as symbolic representation. Otchere-Larbi (2009) also stated that, in a given parabola that does not show the y-intercept on the visible part of the graph, students conclude that such a point does not exist. Students also showed some level of difficulties on questions relating to a single quadratic task. The researchers revealed that equations on a horizontal translation function like a parabola $y = (x - 2)^2$ and its relation $y = x^2$ posed a lot of difficulties to student.

2.5 Summary

In this chapter, a literature review was conducted to gain a better understanding of the study. Scholarly books, Professional journals and articles were used to gather information for the study, which provided in-depth knowledge of previous research activities in the area. While some approaches can help students solve quadratic equations by the graphical method, the literature in this chapter suggests that students should be engaged in activities that allow them to apply and develop their critical thinking skills. Furthermore, knowledge construction must be built on the foundation of prior experiences, and a meaningful social learning context.

Following a review of various theoretical and empirical studies aimed at providing guidelines for improving competencies. It was discovered that the constructivist approach is more suitable for enhancing students' performance. The teaching and learning of solving quadratic functions by the graphical method involves the combination of approaches and hence enable students adopt the required concept. The concept of approaches that are useful in teaching of solving quadratic functions by the graphical methods in general are covered in the literature review.

Solving problems of quadratic functions should not only be memorization of rules and formulas but should also be based on procedures for the purpose of developing deeper understanding of mathematics ideas and concepts.

From the above findings, it is thus evident that the use of constructivist approach to teaching and learning of mathematics, which is difficult in practice, can be very effective by helping the students to get the concept better as well as improving their performance.

CHAPTER 3

METHODOLOGY

3.0 Overview

This chapter discusses the entire methods that were employed in the collection of data for the study. The research method used in this study is informed by the purpose of the study, which is to use constructivist approach to enhance students' performance in solving quadratic equations by the graphical method, and the type of data needed to answer the research questions outlined in section 1.5. The questions are:

1. What are the difficulties and errors do SHS students make when solving quadratic equations by the graphical method?
2. What effect do constructivist instructional approach have on students to improve their performance in solving quadratic equations by the graphical method compare to the conventional approach?
3. What are the views of students on the effective use of constructivist approach on SHS 2 students?

This chapter gives a description of the study area, research design, the target population, sample size and sampling techniques, construction of research instruments, treatment process and validity of the instrument, reliability of the instrument, data collection procedure, data analysis procedure. Finally, ethical considerations and summery for the study

3.1 The Study Area

The study was conducted in Potsin T.I Ahmadiyya Senior High School, Gomoa-Potsin. The school is located in Potsin Township. Potsin is a town in the Gomoa East district, which is part of the Central Region of Ghana. The Gomoa East district has three Senior

High Schools, Potsin T.I Ahmadiyya Senior High School, Feteman Senior High School and St. Gregory Catholic Senior High School. Potsin T.I Ahmadiyya Senior High School is graded 'B' school according to the Ghana Education Service classification. It offers the following courses: Science, Agriculture Science, Technical, Business, Home Economics, General Arts and Visual Arts. There are eighteen classes at each level. Out of the eighteen classes, eight of the classes offer General Art and one of the General Art classes was selected for the research. The overall performance of the school in the WASSCE examination can be describe above average. With respect to core mathematics, the performance of the students has not been encouraging.

3.2 Research Approach and Design

3.2.1 Research Approach

Mixed methods research approach, which combines both quantitative and qualitative data, was used in this study. The purpose for combining quantitative and qualitative data collection and analysis procedure in this study is to provide a better understanding of the research problem and the research question than is possible using a single approach (Creswell & Clark 2007).

3.2.2 Research Design

The research design describes the major procedure to be followed in carrying out the research. According to Bless and Higson-Smith (1995), research design is a specification of the most adequate operations suitable to the specific research goal. Similarly, the ultimate goal of a good research design is to guide the researcher on the types of data collected, how to collect, process and analyze them in order to answer the research questions or test the research hypothesis (MacMillan & Schumacher, 2001 p.

166). The study sort to investigate the effect of constructivist approach to enhance students' performance in solving quadratic equations by the graphical method.

In this study, a sequential explanatory design was used consisting of two distinct interactive phases, the beginning with the collection and analysis of the quantitative data to expand the first phase quantitative results followed by the designing of the second, qualitative phase on the basis of the quantitative findings (Creswell & Plano Clark, 2018; Wisdom & Creswell,2013). Quantitative research methodology was used for the collection and analysis of the quantitative data. Within this methodology, the study adopted quasi-experimental non-equivalent group design with a pre-test and a post-test (Gray, 2013). The word "quasi" means partial, half, or pseudo. Quasi-experimental design can be used when it is not possible for the researcher to randomly sample the subject and assign them to treatment groups without disrupting the academic programs of the schools involved in the study Gall et al (2003).

The quasi-experimental research bears a resemblance to true experimental research, but are not the same. According to Ary, Jacobs and Razavieh (2002), quasi-experimental design are research design, which do not include randomization and are used when true experimental research is not feasible. The quasi-experimental research is a very common research design used in educational research, where administrators are unwilling to allow the random selection of students for experimental samples.

The non-equivalent group type of quasi-experimental design was considered appropriate for this study at the expense of true experimental design, because it was quite difficult to be authorized to apply true experimental design in the Senior High School in Ghanaian classroom settings for this study. This was due to the fact that the research was conducted during school contact periods and no institution would enable a researcher to divide classes already assigned to students into multiple academic programs for the purpose of research. As a result, it was impossible to allocate students to groups at random. This denotes that other randomization-based research designs were ruled inappropriate and unethical for this investigation.

The non-equivalent group type of quasi-experimental design was used to enable the researcher assign members to a control and experimental group. The experimental group was taught using the constructivist instructional approach while the control group was taught by the conventional instructional approach. The Quasi-experimental design sought to examine the difference in performance of the two groups (experimental and control group) to determine whether the constructivist teaching approach had an effect on improving students' performance in studying quadratic equations. As a result, the main goal of the research is to see how large the difference in performance is when the treatment is implemented. The pre-test and post-test were analyzed quantitatively. That is the scores obtained by the participants in the pre-test and post-test was organized into frequency distribution tables. The means and standard deviations were then calculated and used to test hypothesis as to whether there was significant improvement in the performance of students in the post-test or not.

The second phase focused on the collection and analysis of qualitative data by the qualitative methodology where within this method the study used interview. The responses obtained by the participants in the interview, was analyzed thematically to provide information to answer the research question three (3).

3.3 Population

A population is a group of elements whether individual, object, or events, that conform to specific criteria and to which we intern to generalize the results of the research. The target population for this study consisted of all the second year students in Potsin T.I Ahmadiyya Senior High School in the Gomoa-East District in the Central Region of Ghana. The accessible population was all the Form Two General Art students of Potsin T.I Ahmadiyya Senior High School which is made up of five classes with a total population of one hundred and eight-five (185) students.

3.4 Sample and Sampling Techniques

3.4.1 Sample Size

A sample offer more detailed information and a high degree of accuracy because it deals with relatively small number unit (Gravetter & Forzano, 2006). The sample size for the study was made up of two intact class of all the Form Two (2) General Art Two 'A' (2GA2A) and Form Two (2) General Art two 'B' (2G2B) students in Potsin T.I Ahmadiyya Senior High School consisting of fifty-five (55) students, representing 30% of the entire accessible population. The researcher chose these two intact classes because most mathematics teachers and students have the notion that students offering elective mathematics perform far better in core mathematics than those who do not. As a result, the main goal of the research is to see how large the difference in performance is when the treatment is implemented. Forty-four (44) of them were female and eleven (11) were male. Their ages range between sixteen (16) and seventeen (17) years.

3.4.2 Sampling Techniques

Sampling refers to the process and techniques used to select participants for a study. The purposive sampling and convenience sampling techniques are employed by the researcher in obtaining the samples Two (2) General Art Two 'A' (2GA2A) and Form Two (2) General Art two 'B' (2GA2A and 2GA2B) for the study through the selection of the year group, class, the control and the experimental group for the study. Purposive sampling and Convenience sampling techniques are used when the researcher wants to select only the cases that might best illuminate and test the hypothesis of the research (Tashakkori & Teddlie 1998). Again, Creswell (2005), they are used when, lack of time and financial constraints make it impossible to conduct a large-scale study.

According to Given (2008), convenience sampling is a sort of inspecting where individuals from the objective population that meet certain down to earth criteria, for example, sample openness, geological closeness to take an interest are incorporated with the end goal of the investigation.

Convenience sampling is a technique where members of the target population that meet certain practical criteria, such as easy accessibility and proximity to the researcher, availability at any given time, or the willingness to participate are included for the purpose of the study. The reason for conveniently selecting the two intact class and the year group from the school was that:

- The study adopted the quasi-experimental experimental design where randomization is not adhered to.
- The students were taught all the lessons during the instructional time.
- The topic used for the research was one of the form two topics in the mathematics syllabus for SHS.
- The students were not under any immediate external examinations that could distract them from fully participating in the study.
- The students in the experimental group had done the topic with a different teacher who used the traditional method of teaching and are much conversant with that teaching style therefore, are likely to make better comparative judgement on the new intervention.

Purposive sampling technique is the deliberate choice of a participant due to the qualities the participant possesses (Bernard, 2002). In purposive sampling, the units of the sample are selected not by a random procedure, the researcher decides what needs to be known and sets out to find people who are willing and can provide accurate information by virtue of knowledge or experience. It therefore involves the identification and selection of individuals or groups of individuals that are proficient and well informed with a phenomenon of interest (Creswell & Plano Clark, 2011). The researcher purposefully selected the two intact classes (2GA2A and 2GA2B) and assigned them to control and experimental group.

The researcher selected 2GA2B class as the experimental group not by random procedure but was assigned as the experimental group because it was here that the problem was identified. This was possible based on their poor performance in mathematics during the pre-test on this topic after scoring the marks. From the pre-test, the researcher also identified this class as having a serious challenge with mathematics. There has also been a general perception of the students in the school that General Art students who do not offer elective mathematics as one of their elective subjects do not show much interest in the study of mathematics, hence the study could help determine whether the treatment would help improve their performance in the mathematics subject especially solving quadratic equations by the graphical method or not.

For the control group (2GA2A) out of the fifty-five (55) students available for the study, thirty-two (32) students made of twenty-eight (28) females and four (4) males fully participated. whilst for the experimental group (2GA2B) out of the fifty-five (55) students available for the study twenty-three (23) students made of sixteen (16) females and seven (7) males fully participated.

The grouping was done in order to manipulate the independent variable (experimental group) by exposing them to a treatment (constructivist teaching method) by the researcher in order to test the effect of this manipulation on the dependent variable (control group) that were not exposed to any treatment. The control group was similar to the experimental group in terms of age, gender, race etc.

3.5 Research Instruments

Research instruments are tools used for collecting data for a study. In view of the nature of the research questions and the type of research design adopted, the researcher used two instruments to collect data for the study, thus test (pre-test post-test item) and unstructured interview guides. The test item covers student's knowledge about the concept on solving quadratic equations by the graphical method.

3.6 Intervention Design and Implementation

This sub-section of the study describes the systematic procedures and strategies that were put in place to enhance students' performance in solving quadratic equations by the graphical method. The major intervention used by the researcher was the constructivist teaching approach. The action plan for the study was divided into three sub-sections: pre-intervention, intervention (implementation) and post-intervention.

3.6.1 Pre-Intervention Stage

In order to ascertain whether the problem of students' difficulty in solving quadratic equations by the graphical method really exist, a written diagnostic test (pre–test) was developed and administered to both intact group (thus the experimental and the control group) respectively by the researcher.

Diagnostic testing is the process adopted to locate and identify students' areas of learning difficulties and weaknesses in a subject or skill and the cause. It implies a detailed study of learning weaknesses (Ketterlin-Geller & Yavanoff, 2009). Performing diagnostic testing to the student enabled the researcher to determine the nature and the cause of students' learning difficulty, with the main purpose of correcting and remedying the difficulty involved. It helped the researcher to diagnose and identify the specific problems each of the students had in studying the topic. That is, to locate the particular area where the difficulty lies or the particular concept where the student commits errors. Hence, the main aim of diagnostic testing is to find out a student's weak learning point and not how much the student scores (Ofem, Idika, & Ovat, 2017).

The total number of students used for the pre–test consisted of fifty-five students (n=55). The pre-test contained ten (10) multiple-choice question test items; each was scored a mark and two subjective questions test items with sub-questions where students will provide their own answers; each was scored five marks. The pre-test was conducted to check out student's errors in solving quadratic equations by the graphical method. The construction of the test items was guided by the instructional objectives associated with solving quadratic equations by the graphical method in the SHS Mathematics Syllabus, from specific objectives 2.6.1- 2.6.4 (Ministry of Education, 20007) Page. 30-31, Core Mathematics Text Books and WASSCE past questions. Students were given forty (40) minutes to answer the questions. The researcher and other mathematics teachers invigilated the student after which the script was collected, and the answers given by students were marked with a marking scheme prepared by the researcher. The researcher examined the answers given by students and critically examined the common errors and weaknesses of the students. Most students were not able to:

- use the relations given to them to complete the values of table.
- choose a suitable scale to work to draw the graph.
- join the ordered pairs they have plotted on the graph to get a smooth curve to make the quadratic graph, the graphs were incorrectly drawn.
- use their free hands to draw the attain quadratic curve neither could they interpret their own graphs.

Again, some of the shapes also have sharp point, outward asymmetric curve, kink shape, flat nose, s-shapes curve, and half cup-shapes. Discussions were held with students to find out why they answered some question in the way they did, the pre-test was marked over twenty (20) marks and scores recorded and presented as data. After analyzing the data, it became evident that the difficulties students face in solving quadratic equations by the graphical method had been caused by the following factors:

- Inappropriate teaching and learning methodology used for teaching the concept "solving quadratic equations by the graphical method".
- Teacher's content knowledge and the approach to teaching of the mathematics subject.
- Lack of motivation and interest in the topic "solving quadratic equations by the graphical method".
- Inadequate teaching and learning materials to be used to explain the concept.
- General perception that mathematics is a difficult subject to learn.

From the above information gathered as to why students performed poorly in the Pre-Test, only inappropriate teaching and learning methodology used for teaching the concept “solving quadratic equations by the graphical method” was relevant and therefore became the focus of this study.

3.6.2 Intervention and Implementation Stage

After the pre-test, a four (4) week intervention was administered by the researcher. Total number of students used for the lesson was fifty-five (55). The intact class was put into two groups. The experimental group were twenty-three (23) in number (female 16, male 7) was taught by the researcher using the constructivist approach (student-centered) while the second groups (control group) made of thirty-two (32) in number (female 28, male 4) was taught by the class teacher using the traditional teaching method (student-centered). Each group was met twice in a week during which 60 minutes’ lesson was prepared and taught for each meeting.

The following were the sub-topics treated:

- Definition of quadratic function.
- Drawing table of values
- Choosing correct scale
- Plotting of points in the Cartesian plane and drawing graph of quadratic function.
- Interpretation of quadratic function (finding solution set. Equation of line of symmetry. Minimum and maximum value or point of quadratic graphs).

3.6.2.1 Treatment of the Control Group: The Conventional Approach

This teaching method includes teachers utilizing chalk and board and students using pen and paper. The teacher offers the input/feedback orally or on the board, and students carefully follow the teacher's instructions, with no encouragement for active engagement from the students. The students sit in their seats as they listen and watch the teacher explain the materials to them. Students are not encouraged to talk to one another or interact with one another. The teacher does much of the teaching and analytical activities. The teachers' explanations and textbooks were the primary teaching strategies without directly considering students' alternative conceptions. Before the lesson, the students independently studied their textbooks, and the teacher organized the whole class as a unit, solving examples on the chalkboard, and defining few phrases. The primary underlining principle was that, knowledge belongs to the teacher and that it is the teacher's responsibility to pass on that knowledge as facts to the students. About (80-95%) of the class time was spent on instruction and engaging in discussion based on the teacher's explanations, questions and solutions.

3.6.2.2 Treatment of the Experimental Group: Constructivist Approach

To improve the performance of students in solving quadratic equation by the graphical method, the researcher prepared a constructivist-based teaching approach that was used with the experimental group for four (4) weeks and two (2) weeks for the pre-test and post-test. Due to the students' poor performance on the pre-test, the researcher devised a series of treatment activities to take students through the process of plotting and interpretation of the graphs to improve their knowledge in solving quadratic equation by the graphical method.

The students were put into groups of four (4) and each group nominated a leader. The researcher used a mixed ability grouping which was based on student's interest, competence, gender, attitudes and socio-economic background to carry out the activities. The students were provided with graph sheets. The students were given the platform to freely discuss and interact with each other before the leader collates their responds and presented their ideas to the researcher. The students were given enough activities to enable them investigate the properties of the quadratic function to came out with their own findings. One unique feature of the Constructivist Teaching Approach was that, it was difficult to differentiate between the researcher and the students as the researcher moves from group to group in order to monitor, provide assistance and direct learners' discussion. All the teaching and learning activities in this constructivist lesson were centered on the students. The students demonstrated more enthusiasm and interest in the subject matter. Individual differences among students with respect to their speed of learning or their knowledge background was taken into account in the study. The researcher motivated hardworking students in the class. Help was given to student with difficulties. The intervention was structured as follows:

Week 1:

Day 1: The researcher introduced herself to the class, explaining to them about the thesis and the importance of their participation in order to complete the task successfully. Students were promised that the test would not affect their exams score and that their assistance would aid in the production of good research work that would allow the researcher to adopt the best methods for helping them understand mathematics better.

The researcher asked the students if they had been taught solving quadratic equations by the graphical method. Students agreed that the topic was taught to them by a different teacher in form two first term. The constructivist method was used to guide the intervention. The methods are as follows: in the classroom, the constructivist teacher (the researcher),

- Modified instructional strategies in the process of teaching based upon students' thought, experience and interest.

- The activities that were put to practice was student centered, this placed the student in a central position in the classroom.
- Organized and managed the classroom environment in a democratic manner that emphasized on shared responsibility and decision-making between students-students and teacher- students.
- Invited student's questions and ideas on the topic thought.
- Accepted and encouraged students' invented ideas, which motivated them to learn.
- Encouraged student's leadership, cooperation, seeking information, and presentation of ideas.
- Encouraged free discussions among group members by way of bringing new ideas on board, inviting student questions and answers. As the students interact with the researcher and their peers, they practice using language in a variety of contexts developing and honing many different skills as they do so.
- Helped students to test their own ideas.
- Invited students' ideas, before the students were presented with the ideas and instructional materials.
- Encouraged students to challenge the concepts and ideas of others.
- Used cooperative teaching strategies through students' interactions and respect and use other people's ideas, sharing ideas and learning task.

The constructivist teaching methods proposed by Yager (quoted in Kim, 2005) was also used that is, according to this method, as the first step, the instructor ask the student some questions at the beginning of the lesson in order to activate students' prior knowledge, encourage student-student interaction and agreement before presenting the concept.

Day 2: lesson on definition of quadratic function and drawing table of values.

The researcher introduced the lesson by relating it to shapes in our everyday lives.

The researcher asked questions such as:

1. What is the shape of the bow?
2. What is the shape of the Adomi Bridge?
3. What shape is form when a volleyball player decides to serve the ball?
4. What is the shape of a satellite dish? etc.

Are they curve or straight line?

Students were asked to brainstorm to come out with the definition of quadratic function.

Student were assisted to build table of values with a given relation.

Week 2: Lesson on choosing correct scales, plotting of points in the Cartesian plane and drawing graph of quadratic function.

Day 1: Students were put into groups of four and each group appoints a leader. The students were provided with graph sheets, rules, erasers and pencils. The students were assisted as to how to choose correct scale and plot points in the Cartesian plane of a given quadratic function.

Day 2: With the points plotted, students were asked to use their free hands to join the plotted points to form a smooth curve. The students were asked to identify the shape they have drawn.

Week 3: Lesson on interpretation of quadratic function.

Day 1: Finding solution sets and equation of line of symmetry. The researcher assisted the students to find the solution set of the quadratic equation from the graph and established that the quadratic graph is symmetrical about a vertical line ($x - axis$).

Day 2: Finding the minimum and maximum value or points. With the graph drawn, the researcher asked the students to identify the minimum and maximum value or points of the graph and state the coordinate of the points where these occurs.

Week 4: Lesson on interpretation of quadratic function.

Day 1: Finding the range of value of x as y increases or decreases, range of value of x as $y > 0$ or $y < 0$. The researcher asked the students to discuss and come out with their own finding of the range of values of x for which the graph is increasing or decreasing.

Day 2: Finding the gradient of a curve. The researcher demonstrated to the students how to find the gradient of a curve. The students were given the opportunity to discuss and find the gradient of the curve they have drawn. In the course of the discussion, they understood their own and others' ideas, defend their answers, and come to a consensus about the question. The researcher did not interact with the students throughout this time. They were at liberty to formulate their tentative responses. Following that, each group provided the researcher with a common response.

3.6.2.3 Post Intervention Stage

After four (4) weeks intervention, ten (10) standardized achievement test (post-test) questions were administered to both the control group and the experimental group around the same period using similar standard test items of the pre-test to find out if the intervention strategies used made any impact on students' performance. The post-test contained ten (10) multiple-choice question test items; each was scored a mark and two subjective questions test items with sub-questions where students will provide their own answers; each was scored five marks. The construction of the test items was guided by the instructional objectives associated with solving quadratic equations by the graphical method in the SHS Mathematics Syllabus, from specific objectives 2.6.1-2.6.4 (Ministry of Education, 20007) Page. 30-31, Core Mathematics Text Books and WASSCE past questions. The post-test was not exactly the same as the pre-test with the reason being that if the intervention had been effective, then students should be able to answer similar questions on the topic. The students were given the same time (forty (40) minutes) as it was allocated for them in the pre-test. The researcher and other mathematics teachers invigilated the students after which the scripts were collected, marked over twenty (20) and the scores recorded and presented as data. It was realized that students who were taught using the constructivist teaching approach (experimental group) responded more positively and their performance in solving quadratic equations by the graphical method has been improved tremendously than the students who were taught through the conventional teaching methods (control group).

3.7 Unstructured Interview

Unstructured interviews are the most commonly employed data collection method used to collect qualitative data. An interview is a method of data collection that involves two or more people exchanging information through a series of questions and answers. Three types of interviews can be distinguished in educational research: the structured interview, semi-structured interview and unstructured interview (Bryman 2004). Aside from the diagnostic and standardized achievement test, an unstructured interview was used to address the research question: What are the views of students on the effective use of constructivist approach on SHS 2 students?

According to DePoy and Gitlin (1998), Fontana and Frey (2003) and Patton (2000), In an unstructured interview the interviewer may have one or two themes that he or she want to talk about, but generally follow the lead of the interviewee. Unstructured interview is an interview that do not use any set questions, instead, the interviewer asks open-ended questions based on a specific research topic, and will try to let the interview flow like a natural conversation. The interviewer modifies her questions to suit the candidate's specific experiences. Unstructured interviews are sometimes referred to as 'discovery interviews' and are more like a 'guided conservation' than a strict structured interview. They are sometimes called informal interviews (McLeod, S. A. (2014, February 05). This unstructured interview was chosen in this study to other qualitative instruments due to the following reasons:

- The unstructured interview is more flexible as questions can be adapted and changed depending on the respondents' answers.
- It generates qualitative data through the use of open questions. This allows the respondent to talk in some depth, choosing their own words.
- It also gives the interviewer the opportunity to probe for a deeper understanding, ask for clarification and allows the interviewee to steer the direction of the interview.

The interview was in the form of individual face-to-face section. According to Neuman (2007), face-to-face interviews have the advantage of high response rate and permit the interviewer to observe non-verbal communication and use extensive probes. The individuals' face-to-face interview section was considered desirable rather than the group interview for this study because of insufficient resources to conduct group discussions, which requires the recruitment of the participants, their preparation and the search for a venue, which is appropriate for all the participants (Craike 2004). Again, confidentiality and anonymity are the two main ethical considerations with which this study strives to protect respondents' responses and identities, hence, using group interviews would have violated these ethical principles.

Ten (10) students were selected at random from the sample for the interview. The unstructured interview guide consisting of ten (10) items was used to elicit information on the students' impressions about the use of the constructivist approach to teaching "solving quadratic equations by the graphical method". At most five (5) minutes was spent on each student. The students' response from the interview was transcribed and analyzed to help the researcher in interpreting the qualitative result. The analyzed data provided information in addressing the research question three.

3.8 Validity of Research Instrument

When an instrument is valid, it means it measures adequately what is expected to measured. Thus, validity of instrument determines whether the research truly measures that which it was intended to measure or how truthful the research results are (Joppe 2000). Four types of validity exist: construct, face, criterion and content validity. In this study, with regard to content validity, it refers to the extent to which the test item measures a representative sample of the subject matter treated. The test item was constructed based on the instructional objectives and the specific objectives in the SHS curriculum. In order to be sure that the test items for the study were valid, the test items were given to the researchers' supervisor for thorough examination to ensure that the items measure the content area (content validity) of the study. Fellow graduate students in the Department of Mathematics Education, University of Education, Winneba were also given the opportunity to study the items to comment and make the necessary corrections on them. The test items were also given to a colleque mathematics tutors in the SHS to crosscheck and contribute to the content areas that were tested in the study in order to further ensure that the content that was chosen was within the approved domain of the study for the SHS students concerned. After this has been done, the researcher went through the test item very carefully noting every comment with great concerned. The test items were then altered again before finally administered to the students as well as the face-to-face interview.

3.9 Reliability of Research Instrument

De Vos, (2002) refers reliability of an instrument is the degree to which independent administration of the same instrument (or highly similar instruments) consistently yield the same result under comparable conditions. It measures consistency, precision, repeatability, and trustworthiness of a research (Chakrabartty,2013). Reliability is used to evaluate the stability of measures administered at different times to the same individual and the equivalence of sets of items from the same test (Kimberlin & Winterstein,2008). The methods for establishing the reliability of an instrument include the test-retest method, alternative form method, split half method, or calculation of the chronbach's alpha coefficient (De Vos, 2002). In order for the results from a study to be considered valid, the measurement procedure must be reliable. For reliability and effectiveness of the instruments (test item) to be proven in this study, the researcher used the test-retest reliability methods. The reliability coefficient is obtained by repetition of the same measure on a second time, is called the test-retest reliability (Graziano & Raulin, 2006). The same instrument was administered twice to the same participants of fifty (55) students at different time intervals and the result was assessed to check reliability (test-re-test method to be employed). Reliability analysis was done using Cronbach's alpha reliability model to measure the internal consistency of the instrument by estimating the average correlation that was obtained by the respondents. The responds of the respondents (control group and experimental group) yielded a reliability coefficient of 0.75 and 0.85 respectively. The reliability coefficient of equal to or more than 0.70 threshold is acceptable as a measure of reliability as noted by Tavakol, Mohagheghi.and Dennick (2008) who have stated that the acceptable values of alpha, ranges between 0.70 and 0.95. Since the two (2) reliability coefficient of the respondents were between 0.70-0.95 therefore predicted that the instruments were reliable.

3.9.1 Data Collection Procedure

For ethical reasons, a letter of introduction stating the topic and purpose of the study was obtained from the Head of Department of Mathematics of the University of Education, Winneba to introduce the researcher to the headmaster in charge of academics of the school to enable the researcher conduct the study. This was to ensure maximum support, proper reception and the cooperation of the participants in question.

Data was collected using pre-test post-test and unstructured interview guides. A pre-test was administered to both groups (control and experimental group) by the researcher in the first week. The test was graded, analyzed to identify students' strength, weakness, errors and difficulties in solving quadratic equations by the graphical method. After the pre-test, the group of students were subjected to four (4) weeks treatment. During the treatment period, 60 minutes' lesson was prepared and taught for each meeting. The researcher and the class teacher met the students in each class (control and experimental groups) twice a week for lesson, with the experimental group receiving the constructivist approach and the control group receiving the traditional approach. The lesson was designed based on solving quadratic equations by the graphical method. In the sixth week, the researcher administered the post-test and the interview guide. The Pre-test and Post-test were used in collecting a quantitative data that helped the researcher with more information in answering research question 1 and 2, thus to examine the effect of constructivist approach to improve students' performance in solving quadratic equations by the graphical method. After the post-test, a fifty (50) minute unstructured interview guide consisting of ten (10) items was administered to Ten (10) students selected at random from the sample. The interviewees were guaranteed of confidentiality to prevent their identities from being revealed before the interview. The unstructured interview was used in collecting a qualitative data that helped the researcher with more information in answering research question 3. The researcher administered the test-items and the unstructured interview personally

3.9.2 Data Analysis Procedure

This is the process of systematically applying statistical techniques to describe data. The purpose of the analysis is to make meaning out of the data gathered in relation to the research problem at hand. This data analysis usually involves reducing the raw data into a manageable size, developing summaries and applying statistical inferences. The instruments used to collect the data requires that the data be analyzed both quantitatively and qualitatively. Tashakkori and Teddlie (2008) as cited by Assuah, Yakubu, Asiedu-Addo & Arthur (2016), this approach was used because neither method (qualitative or quantitative) is individually sufficient to thoroughly capture the details of the study. When used together, both methods complement each other to provide a more complete picture of the situation being studied. Students were made to write a pre-intervention test before the lesson based on constructivist instructional approach was used to teach solving quadratic equations by the graphical method. Students were taken through solving quadratic equations by the graphical method concept for four weeks after completing the lesson, students were made to respond to post invention test.

The data collected by the students through the pre-test post-test was analyzed quantitatively using Statistical Product for Services Solution (SPSS) version 21 and Microsoft Excel 2007 and this was put in tables and figures as frequency, percentage, mean and standard deviation. The sample t-test was used to compare the differences between the mean and standard deviation scores at 0.05 level of significance and this answers the research questions: (ii) what are the difficulties and errors do SHS students make when solving quadratic equations by the graphical method? and (ii) what effect do constructivist instructional approach have on students to improve their performance in solving quadratic equations by the graphical method compare to the conventional approach? Though a sample of n=55 was used, according to Marques de sa (2007), the t-test statistics was used because most of the software products, for simplicity and approximation, uses the t-statistics irrespective of the value of the sample size ‘n’. The data collected through interview was also analyzed qualitatively by using the thematic approach of analysis to answer research question (iii) What are the views of students on the effective use of constructivist approach on SHS 2 students? The SPSS soft wear was chosen for the data analysis upon any other alternatives not only because of its’ user-friendly but also easily applicable in any kind of quantitative analysis (Arkkelin, 2014).

3.10 Ethical Consideration

Ethics are norms or rules for conduct that focus on what is morally proper and improper when engaged with participant. Ethical standards prevent against the fabrication or falsifying of data therefore, promote the pursuits of knowledge and truth which is the goal of research. Respecting of the site where the research takes place and gaining permission before entering a site is paramount in research (Creswell 2002). The researcher made the participants aware that her interaction with them is purely for academic purposes and that whichever information given would be kept in a high confidential manner and be treated as anonymous as possible. According to Kelley et al (2003), these are the most important ethical issues to adhere to when conducting research.

3.11 Summary

The general design of this study was a mixed method approach that included both qualitative and quantitative methodology. The study involved fifty-five (55) students of Potsin T.I Ahmadiyya Senior High School form two (2) Genera Art Two ‘A’ (2GA2A) and Genera Art Two ‘B’ (2GA2B) class. The main research instrument in the quantitative phase was a test instrument (pre-test post-test item). The study began with the administration of a pre-test which was diagnostic test to both groups (experimental and control) on solving quadratic equations by the graphical method. The pre-test was to ascertain whether the problem of students’ difficulty in solving quadratic equations by the graphical method really existed and identify the root-cause of students’ problem. After the pre-test, the researcher organized a four (4) weeks intervention. The intervention was to help students overcome their problems with the use of constructivist teaching approach after which the students were made to write a post-test to find out whether student’s performance in solving quadratic equations by the graphical methods had been improved tremendously with respect to the usage of constructivist teaching approach as planed in the study. The main instrument for the qualitative phase was interview. Ten (10) interview item was used to elicit information on the students’ impressions about the use of the constructivist approach to teaching "solving quadratic equation by the graphical methods". Students' responds to the test items (pre-test post-test) and interview transcripts were used as data source to arrive at valid conclusion about the effect of the use of constructivist teaching approach to improve the performance of students in mathematics. Finally, the researcher discussed the post-test item with the students.

CHAPTER 4

DATA ANALYSIS AND DISCUSSIONS

4.0 Overview

This chapter presents the findings and discusses the results obtained from the pre-test, post-test and the interview of the study. The results of the findings were presented and discussed according to the following research questions:

1. What are the difficulties and errors do SHS students make when solving quadratic equations by the graphical method?
2. What effects do constructivist instructional approach have on students to improve their performance in solving quadratic equations by the graphical method compare to the conventional approach?

   HØ: there is no significant difference in student's performance in pre-test and post-test scores in solving quadratic equations by the graphical method.

   H1: there is a significant difference in student's performance in pre-test and post-test scores in solving quadratic equations by the graphical method.
3. What are the views of students on the effective use of constructivist approach on SHS 2 students?

4.1 Demographic Information of the Participants

The participants for the study were fifty-five (55) students from Potsin, T.I Ahmadiyya Senior High School, Gomoa-Potsin. Out of fifty-five (55) students, thirty-two (32) students were engaged in the control group and twenty-three (23) students in the experimental group. Of the thirty-two (32) students in the control group, twenty-eight (28) which represents 87.5%, were female and four (4) which represents 12.5%, were male. Again, of the twenty-three (23) students in the experimental group, sixteen (16) which represents 69.6% were female while seven (7) representing 30.4% male. Out of fifty-five (55) participants, 80% (n =55) were girls and 20% (n =55) were boys as presented in table 4.1 below.

Table 4.1 Gender of Participating Students

Gender	Control Group		Experimental Group		Total	
	N	%	N	%	N	%
Female	28	87.5	16	69.6	44	80
Male	4	12.5	7	30.4	11	20
Total	32	100	23	100	55	100

4.2 What difficulties and errors do SHS students make when solving quadratic equations by the graphical method? (Research Question 1).

In order to answer research question 1, the researcher analyzed the results of the pre-test to see what problems students had in solving quadratic equations by the graphical method.

The researcher also made an in-depth analysis of student's responds in the subjective question test items with sub-questions where students were asked to provide their own answers in order to identify their errors and difficulty in solving quadratic equations by the graphical method. The difficulties were classified and discussed under the following aspects.

- Finding tables of values
- Plotting of points in the Cartesian plane
- Drawing of smooth curves

- Finding the axis of line symmetry
- Finding the solution set for the graph
- Finding the minimum point of the graph

Table 4.2 Portion of Students difficulty in Solving Quadratic Equations by the Graphical Method for the Control and the Experimental Group

Difficulty		Students with Difficulty		Students without Difficulty	
Aspect	Number of students attempted (N)	Number of students	Percentage (%)	Number of students	Percentage (%)
Q 1(a). Finding table of values	55	19	34.5	36	65.5
Q1. (b) Plotting of points in the Cartesian plane	55	24	44	31	56
Q1.b.(i) Drawing of smooth curves	55	25	45.5	30	54.5
Q1.b.(ii). Finding the axis of line of symmetry	55	35	63.6	20	36.4
Q1.b.(iii). Finding the solution set for the graph	55	37	67.3	18	32.7
Q1.b. (iv) Finding the minimum point of the graph	55	47	85.5	8	14.5

Note: N = number of students.

The results indicate in Table 4.2 revealed that, out of fifty-five (55) students who participated in the pre-test, nineteen (19) students representing 34.5% from both the control and the experimental group who attempted question 1(a) had difficulty while thirty-six (36) students representing 65.5% had no difficulty. On question 1(b), twenty-four (24) students representing 44% from both the control and the experimental group who attempted had difficulty, while thirty-one (31) students representing 56% had no difficulty. On question 1b (i), twenty-five (25) students representing 45.5% from both the control and the experimental group who attempted had difficulty, whereas thirty (30) students representing 54.5% had no difficulty. Moving further to question 1b (ii), thirty-five (35) students representing 63.6% from both the control and the experimental group who attempted had difficulty and twenty (20) students representing 36.4% had no difficulty. On the other hand, thirty-seven (37) students representing 67.3 % from both the control and the experimental group who attempted question 1b (iii) had difficulty, whereas eighteen (18) students representing 32.7% had no difficulty. Also, the result revealed that forty-seven (47) students representing 85.5% out of the fifty-five 55 students from both the control and the experimental group who attempted question 1b (iv) had difficulty, whereas eight (8) students representing 14.5% had no difficulty.

In terms of the aim of this study, the observations in Table 4.2 suggest that majority of the students who participated in this study turn to make errors in solving quadratic equations by the graphical method and seem to lack basic skills in mathematics concepts, most of them also lack the concept of algebraic expression and the property of real number system. It is therefore reasonable to conclude that the poor performance that is depicted by the participants' scores in Table 4.2 could be as a result of these observations.

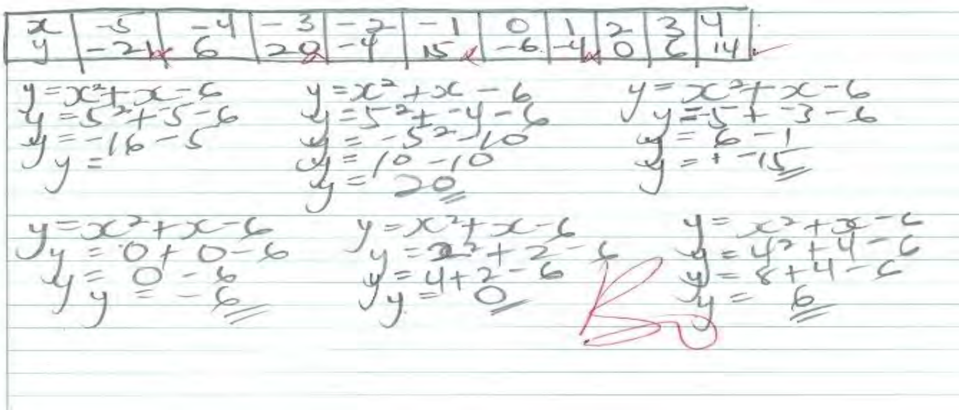


Figure 4.1: Finding Table of Values

The exhibit in Figure 4.1 is a sample of student's response to question 1a(i), here it is observed that the students lack the basic concept of operation on integers and powers of numbers. The student was not able to substitute the x value into the relation

$y = x^2 + x - 6$, when $x = -5$ $y = (-5)^2 + (-5) - 6$ to arrive at

$y = 25 - 5 - 6 = 14$ but rather wrote, $y = -5^2 + -5 - 6$ and had

$y = -10 - 6 - 5 = -16 - 5$ ended there.

Therefore, it can be said that finding table of values is one of the students' difficulties in solving quadratic equations by the graphical methods.

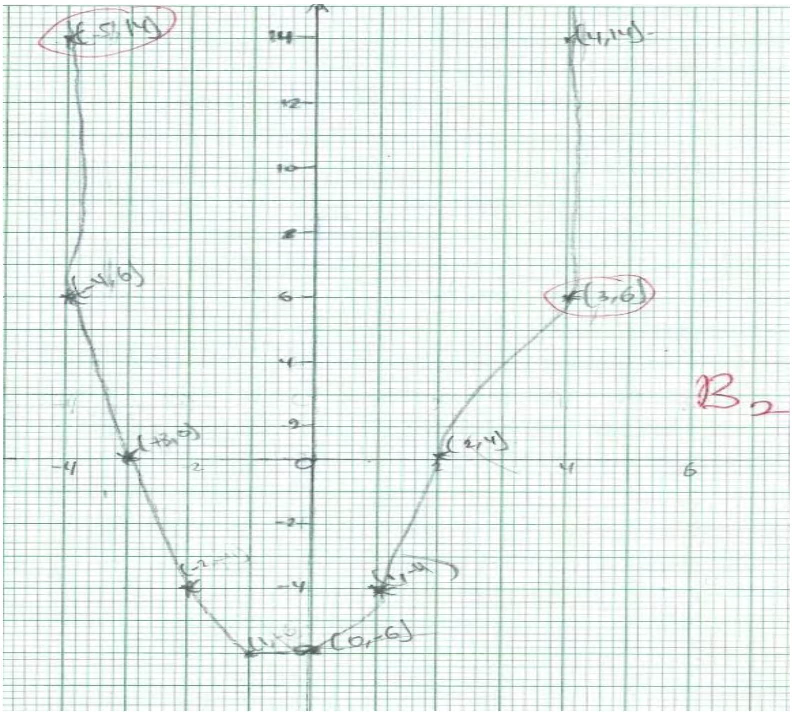


Figure 4.2 Plotting of Points in the Cartesian Plane and Drawing of Smooth Curve

The exhibit in Figure 4.2 is a sample of student's response to question 1a(ii), the student was not able to locate some of the points in the Cartesian plane as well as joining the points to draw a smooth curve.it can be seen that the student understands the concept but he /she had difficulty in solving quadratic equations by the graphical method correctly.

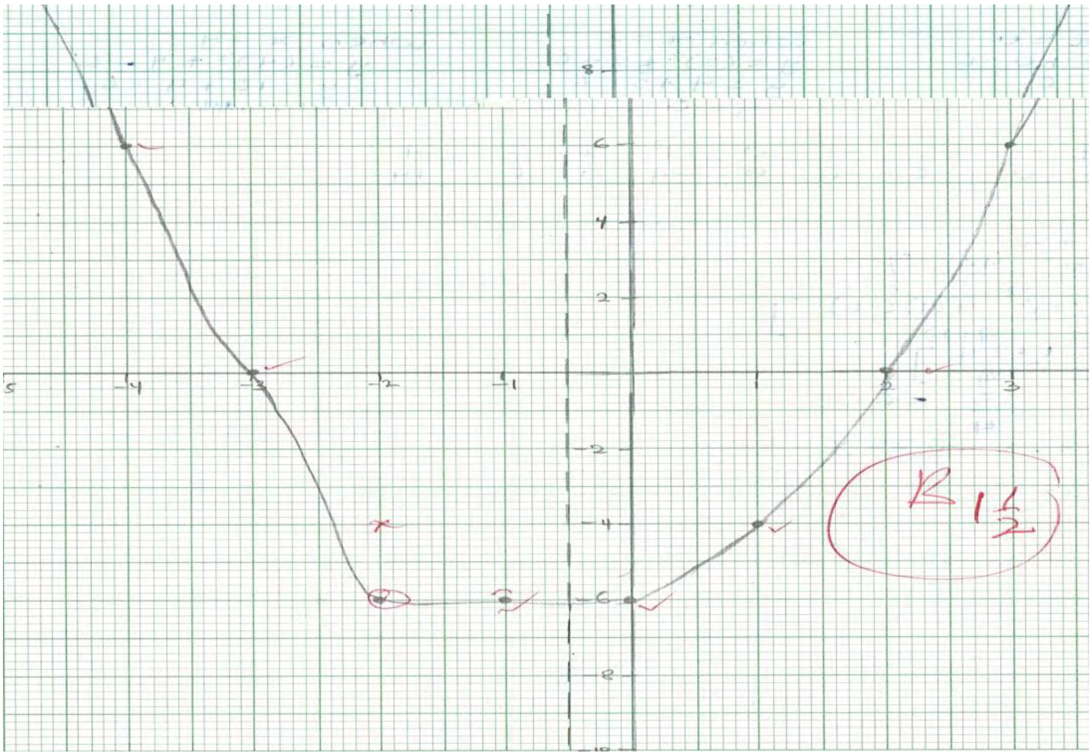


Figure 4.3 Flat Nose Shape

Here, it is observed that, the student was not able to locate the point of the Vertex (turning point) in the cartesian plane that will enable the student draw a sharp curve even though he/she understands the concept. Therefore, it can be said that drawing the sharp curves of quadratic graphs is one of the difficulties in solving quadratic equations by the graphical method.

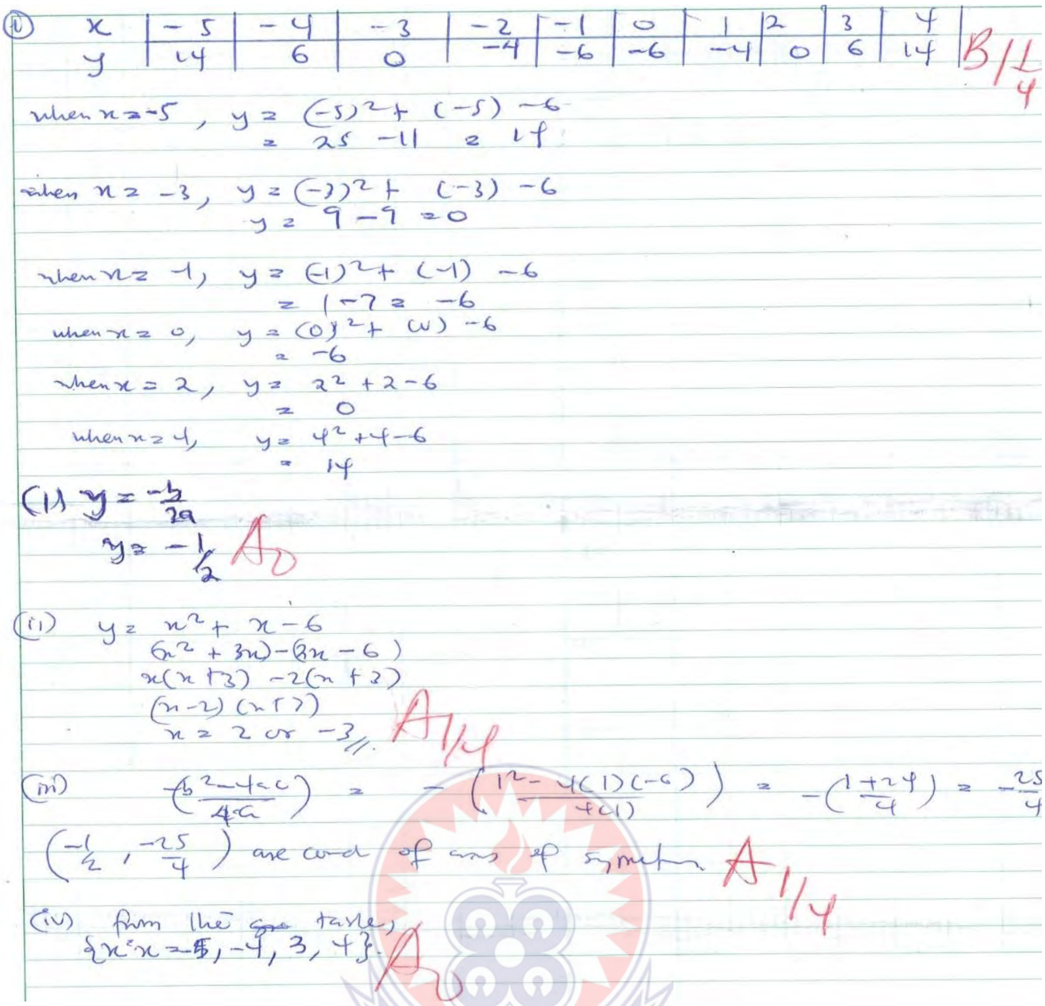


Figure 4.4 Finding the Equation of the Line of Axis Symmetry

The exhibit in Figure 4.4 is a sample of student's response to question 1b (ii), it is a typical example of students attempting to solve the equation but failing to use the right equation. It is observed that the student understood the concept and successfully located the line of symmetry on the graph but failed to interpret it to algebraic equation to reach the solution as required. Again, this demonstrates one of the difficulties students face as they solve quadratic equation by the graphical methods.

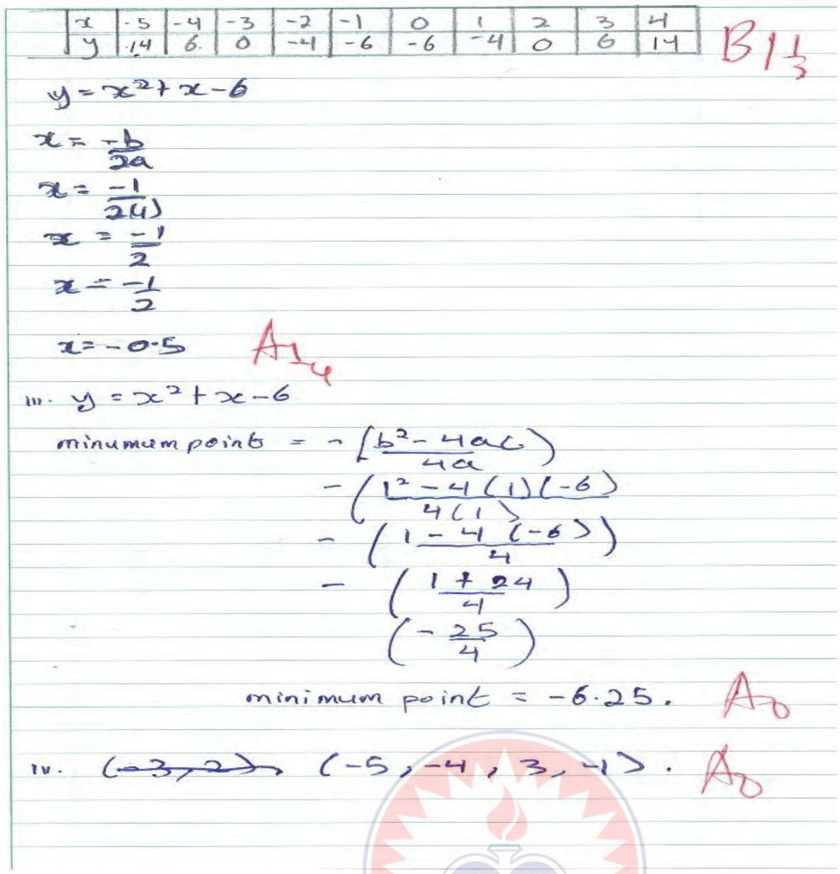


Figure 4.5

Finding the Minimum Point of the Graph

The exhibit in Figure 4.4presents a sample response of students attempting to solve Q1.b. (iv). It is observed that the student had difficulty of differentiating between point and value. This reveals one of the difficulties students face when solving quadratic equations by the graphical method. The findings are consistent with the report of the mock exams of Potsin, T.I. Ahmadiyya Senior High School (2018/ 2019) academic year final year students that, most candidates did not make any effort in answering question on solving quadratic equations by the graphical method even though it was compulsory, and for those who attempted answering, many of them could not handle the question accurately as required because they were not able to read directly from the graph to solve the problem.

4.3 What effect do constructivist instructional approach have on students to improve their performance in solving quadratic equations by the graphical method compared to the conventional approach?

The second research question sought to examine the effect of constructivist instructional approach on students to improve their performance in solving quadratic equations by the graphical method compare to the conventional approach. To do this, the performance of students in the pre-test and post-test of both the control and the experimental group were compared before and after the intervention using descriptive statistics.

4.3.1 Descriptive Statistics

Table 4.3 Percentage Performance of Pre-test Marks for the Control and the Experimental Group

Marks	Control Group			Experimental Group		
(20)	Frequency	Percentage (%)	Cumulative percent (%)	Frequency	Percentage (%)	Cumulative percent (%)
0-5	6	19	19	13	57	57
6-10	14	44	63	9	39	96
11-15	10	31	94	1	4	100
16-20	2	6	100	0	0	100
Total	**32**	**100**	**100**	**23**	**100**	**100**

Note: Analysis of percentage performance of pre-test for both control and experimental group.

Table 4.3 show that out of 32 students of the control group who participated in the pre-test, n =6 (19%) students scored marks from 0 to 5, While n =13 (57%) out of 23 students from the experimental group scored marks falling from 0 to 5. In the 6 to 10 marks category, there were n = 14(44%) scorers out of 32 students from the control group and n = 9(39%) scorers out of 23 students from the experimental group. Moving further to 11 to 15 mark category, there were n = 10(31%) out of 32 students of the control group and n =1 (4%) scorers out of 23 students from the experimental group. In the 16 to 20 marks category, there were only n = 2(6%) scorers out of 32 students of the control group and none of the students from the experimental group scored between 16 - 20 score line. The scores from the table show that as many as n=12(37%) out of 32 students in the control group and n=1(4%) out of 23 in the experimental group scored between the marks of 11-20 whiles n=20(63%) out of 32 students in the control group and n=22(96%) students out of twenty-three (23) students in the experimental group scored between the marks of 0 to 10. Which was regarded as poor performance in solving quadratic equations by the graphical methods?

Table 4.4 Percentage Performance of Post-test Marks of Students Taught with Constructivist Teaching Approach and those Taught without it

	Control Group			Experimental Group		
Marks (20)	**Frequency**	**Percentage (%)**	**Cumulative percent (%)**	**Frequency**	**Percentage (%)**	**Cumulative percent (%)**
0 – 5	6	18.75	18.75	0	0	0
6 – 10	7	21.875	40.625	4	17	17
11 – 15	16	50	90.625	13	57	74
16 – 20	3	9.375	100	6	26	100
Total	32	100	100	23	100	100

Analysis of percentage performance of post-test for both control and experimental group

Table 4.4 show that out of 32 students of the control group who participated in the post-test, n = 6 (18.75%) students scored marks from 0 to 5, While none of the students from the experimental group scored marks falling from 0 to 5. Table 4.4 also show that n=7(21.875%) out of 32 students from the control group scored marks that fell within the 6 to 10 category, while n=4(17%) out of 23 students from the experimental group got the score that fell within this mark category. Moving further to 11 to 15 marks category, there were n= 16(50%) out of 32 students of the control group and n= 13

(57%) scorers out of 23 students of the experimental group fell within this mark category. In the 16 to 20 marks category, only n = 3 (9.375%) scorers out of 32 students of the control group, while n = 6 (26%) out of 23 students from the experimental group fell within this mark category.

The scores from the table show that, n=13(40.625%) out of 32 students from the control group and n=4(17%) students out of 23 students from the experimental group scored between the marks of 0 to 10 while n=19(69.375%) students out of 32 students from the experimental group and as many as 19(83%) out of 23 students from the experimental group scored marks between 11 to 20.

When the scores in the post-test are compared to those in the pre-test, it is clear that students in both groups performed significantly better. However, it appears that the experimental group has had more significant improvement (Table 4.3 and Table 4.4). The use of the constructivist teaching approach, which largely incorporated elements of group learning approach or cooperative teaching strategies, free discussions among group members, classroom environment organized in a democratic manner, lesson based on student-centered, instructional strategies based on students' thought, experience and interest was used to teach ''solving quadratic equations by the graphical method' with the experimental group, is responsible for the significant improvement in students' performance in the experimental group.

Table 4.5 Descriptive Statistics of Students Taught with Constructivist Teaching Approach and those Taught without it

Group	Test	N	Minimum	Maximum	Mean	Std, Deviation
Control	Pre-test	32	1	18	9.09	4.223
	Post-test	32	1	19	10.50	4.912
Experimental	Pre-test	23	1	14	5.39	2.996
	Post-test	23	6	19	13.96	3.470

Table 4.5 shows that the mean scores for the pre-test of the control group was 9.09 and 10.50 for the post-test, and the mean scores for the pre-test of the experimental group was 5.39 and 13.96 for the post-test. These results suggest that there was an increase of (13.96-5.39=8.57) scores in the experimental group as compared to the control group (10.50-9.09=1.41) which is less than the experimental group as a result of the instruction (constructivist teaching approach) that was implemented in this group.

The minimum score students obtained in the pre-test of the control group was 1, while the maximum score was 18. However, in the post-test, the minimum score was 1, while the maximum score was 19. With regards to the experimental group, the minimum score students obtain in the pre-test was 1, while the maximum score was 14. However, in the post-test, the minimum score was 6, while the maximum score was 19. These result show that the minimum and maximum scores of post-test scores were higher than that of the pre-test scores in the experimental group.

In terms of the aim of this study, the observed increase in performance of students' scores in the experimental group was interpreted as suggesting a significant reduction in students' errors and difficulties in solving quadratic equations by the graphical method. Hence, these observations showed that students had improved in their knowledge and understanding of solving quadratic equations by the graphical method.

The standard deviation (±2.996 and ±3.470) of the pre-test and post-test scores of the experimental group and the standard deviation (±4.223 and ±4.912) of the pre-test and post-test scores of the control group show that the post-test standard deviation scores were more than the pre-test standard deviation scores. This is an indication that the post-test score was widely spread around the mean than those of the pre-test (see Table 4.5).

4.3.2 Hypothesis Testing

To determine whether the difference observed in the means are statistically significant between the mean scores of the control and the experimental group in the pr-test and the post-test, the researcher conducted an independent samples t-test on the pre-test and post-test scores of the control and the experimental group to test the research hypothesis.

4.3.2.1 Research Hypothesis

H∅: There is no significant difference in student's performance in pre-test and post-test scores in solving quadratic equations by the graphical method.

H1: There is a significant difference in student's performance in pre-test and post-test scores in solving quadratic equations by the graphical method.

The tables below (4.6(b) and 4.7(b))below presents the result of the Levene's Test for Equality of variance in the pre-test and post-test scores of the control and the experimental group.

Table 4.6:(a) Independent T-test of Pre-test Scores of the Control and the Experimental Group

	Group	N	Mean	Std Deviation	Std Error Mean
Pre-test	Control	32	9.09	4.223	.746
	Experimental	23	5.39	2.996	.625

Table 4.6:(b) Independent Samples T-test of Pre-test Scores for the Control and the Experimental Group

		Levene's Test for Equality of variance		t-test for Equality of Means						
		F	Sig.	T	Df	Sig. (2 tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Pre-test	Equal variance assumed	4.796	.003	-3.600	53	.001	-3.702	1.028	-.5.765	-1.640
	Equal variance not assumed			-3.804	52.998	.000	-3.702	.973	-.5.655	-1.750

The independent sample t-test in Table 4.6 (a) and Table 4.6 (b) show that the pre-test scores for the experimental group (M= 5.39, SD = ±2.996) and the control group (M=9.09, SD=±4.223), t= (-3.804), p =.000 with a mean deference of -3.702 since the significance level of Levene's Test is p< .05, sig(2tailed)< .05 then this means that there was a significant difference between the means of the pre-test scores of the experimental group and control group.

Table 4.7: (a) Independent T-test of Post-test Scores of the Control and the Experimental Group

	Group	N	Mean	Std Deviation	Std Error Mean
Post-test	**Control**	**32**	**10.50**	**4.912**	**.868**
	Experimental	**23**	**13.96**	**3.470**	**.724**

Table 4.7: (b) Independent Samples Test of Post-test Scores for the Control and Experimental Group

		Levene's Test for Equality of variance		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2 tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Post-test	Equal variance assumed	9.111	.004	-2.892	53	.006	-3.457	1.195	-5.854	-1.059
	Equal variance not assumed			-3.058	52.994	.003	-3.457	1.130	-5.724	-1.189

4.4 What are the views of students on the effective use of constructivist approach on SHS 2 students?

To gain a deeper understanding of how students perceive the usage of the constructivist teaching approach. The researcher interviewed ten (10) students in the experimental group to get their opinion on the effectiveness of the constructivist teaching approach to teach solving quadratic equations by the graphical method. There were ten (10) questions on the interview guide that asked students about their experiences and opinions of the use of the constructivist teaching approach. The questions for the interview were directed towards three areas, namely: perception, understanding and preference. Below are some of the interview responses made by the participants during the interview.

4.4.1 Perception

On the issue of perception, the following were some of the interview responses from some of the participants on the interview question: How did you perceive the use of constructivist teaching approach to teach the topic solving quadratic equations by the graphical method? This question was asked to elicit for more information from the respondents on interview item number ten (10) on how they perceive the use of the constructivist teaching approach as compared to the conventional teaching approach.

Interviewee two (2) explained that:

> *the approach is very good, it made the lesson very interesting, the teacher had a dialogue with us which helped us to construct new knowledge, in fact I have really enjoyed the class. I am very happy.*

A similar view was expressed by interviewee five (5) who remarked that:

> *I like everything about the approach because working in small group was a fun and effective method to learn as compared to the traditional methods, it is more engaging, as we were made to collect data and present it in groups. I can now stand in front of my peers and make presentations.*

Interviewee seven (7) shared the same view and explained that:

> *I am so much excited; the approach is very good as compared to the traditional method. No student was left out everybody was involved in the lesson irrespective of our speed of learning, knowledge background, tribe. I wish other subject teachers adopt this method.*

Interviewee one (1) also remarked that:

> *thanks to the method the lesson was more practical. because the learning was interactive and was based on what I already know. I can apply what I was taught to solve common issues in my everyday life.*

These responses from the students suggest that:

when teachers encourage students to take on the role of a teacher, it enhances their learning experience through collaboration. Hence help them to build on their creativity, communication and presentation skills-which are valuable in the modern workplace.

Mathematic concepts can be interesting and easily understood when it is taught in a more practical way. In this regard, Baviskar et al (2009) opined that constructivist learning environment need enough resources which are needed for practical work to enhance students' learning.

Again, active participation of every student is essential in the constructivist method of teaching, it enhances student's thinking skills. In this way, learning can be made fun and creative to attract the students towards studies. Teachers are to incorporate fun activities in their teaching in order to make lessons livelier. Giving the individual student the chance to present and discuss his or her work in class whilst the teacher and the other students listen and question the student about his/her approach to solving a particular problem promotes self-confidence and independent learning among students (Willis 2010).

4.4.2 Understanding

On the issue of understanding, the following were some of the interview responses on the interview question: To what extent did, you understand the lesson, when the constructivist approach of teaching was used for the lesson "solving quadratic equations by the graphical method". This question was asked to solicit for more information from the respondents on interview item number seven (7) on how the constructivist teaching approach has helped them to understand the concept "solving quadratic equations by the graphical method".

Interviewee three (3) explained that:

I like everything about the constructivist teaching approach because it has enhanced my understanding and retention of the concept ''solving *quadratic equation by the graphical method''. I can boldly say, indeed everybody can learn mathematics.*

A similar view was shared by interviewee four (4) that:

the constructivist approach is the best method, the approach has helped me to understand the topic better than when taught with the traditional approach and this will go a long way to improve my academic performance particularly in mathematics.

The comments are in agreement with Blunk & Yager (1990), which found out that students in class taught with a constructivist approach improved more in their understanding of the nature of science when compared to students in classes taught with a textbook oriented approach.

4.4.3 Preference

On the issue of preference, the following were some of the interview responses on the interview question: Give one reason why you prefer the use of constructivist approach to the topic "solving quadratic equations by the graphical method". This question was asked to solicit for more information from the respondents on interview item number nine (9) on as to which of the two methods they prefer.

Interviewee ten (10) explained that:

I prefer the constructivist methods to the traditional methods in the sense that, the teaching involves discussion, inviting new ideas, we were free to speak and ask questions which sustained and aroused our interest in the class. With the traditional method the teacher does everything, we only sit still and listen to the teacher whilst the teacher demonstrates the mathematical methods to us. We only speak when called upon to do so.

Interviewee eight (8) also remarked that:

I prefer constructivist method than the traditional method because the lesson was centered on the students. It was difficult to differentiate between the teacher and the students. The teacher only moves from

> *group to group to monitor, provide assistance and direct our discussions. I can say that the teacher only guides us. 'I was not bored', I was rather motivated to learn. I don't think I will ever forget all that I was taught.*

Interviewee two (2) explained that:

> *I prefer constructivist method because we were made to work in groups. We were given the opportunity to work cooperatively through interactions, respect, sharing ideas and learning tasks. Even though, occasionally there are conflict within the group, the approach has helped me to develop good interpersonal skills where I am able to work and learn with others. The approach has helped me to develop my critical thinking skills and oral presentation skills.*

These responses from the students suggest that:

Group work approach to teaching aims to promote cooperative learning among students. Students learn about learning from their peers as well as from themselves. when students review and reflect on their learning processes together, they pick up strategies and methods from one another to create new knowledge. The creation of such new knowledge depends on the individual's prior knowledge and the conditions of the individual's learning environment and the kind of people with whom the individual learner interacts.

Again, the idea of learning does not just happen by teachers standing in front of the class and lecture, however to the constructivist, learning occurs when the learner discovers the knowledge through the spirit of experimentation and doing (Kalender,2007) this is best described in Confucius, the renewed Chinese philosopher's quote: "I hear and I forget. I see and I remember. I do and I understand." If teachers always spoon feed students with knowledge as a mother does to the weaning child, the students will be immature, lacking the ability to construct arguments about issues and drawing tentative conclusions of situations. They soon forget what they were taught. If they witness the phenomenon being carried out, they may remember through the sensory activity of seeing. Fully engaging students in the teaching and learning processes enables them to personally discover the knowledge or truth.

In a nutshell, the response from the unstructured interview revealed that students had positive perception and feeling about the constructivist teaching method. Overall, the students showed positive attitude toward solving quadratic equation by the graphical methods. Many of the students demonstrated an increase in understanding, achievement, positive feelings and motivation while working with peers in constructivist lesson in mathematics.

4.5 Discussions of Findings

The Preliminary results gathered from the pre-test conducted indicate that majority of the students used for the study had difficulty in solving quadratic equations by the graphical method. This was revealed in the pre-test result when it became apparent that at the end of the diagnostic test, out of 55 students who participated in the study, 14(25%) out of 55 students scored above 10 marks out of 20 marks. These marks were considered as above pass marks whiles 41(75%) out of 55 students scored below 10 marks (below pass mark) out of 20 marks of which was regarded as poor performance in solving quadratic equations by the graphical method. This gave the researcher the evidence that students were having difficulty in the concept of solving quadratic equations by the graphical method. It was realized that, students were finding difficulties in:

- finding table of values
- plotting of points in the Cartesian plane
- drawing of smooth curves
- finding the axis of line of symmetry

- finding the solution set for the graph
- finding the minimum point from the graph

The descriptive statistics (mean and standard deviation) and inferential statistics (independent sample t-test) were employed as statistical techniques with the help of the use of SPSS software to analyze the data at significant level of 0.05. As a result of the analysis, the study found that there has been a remarkable improvement of students' performance in solving quadratic equations by the graphical method by students who received the constructivist teaching method intervention than students who receive the conventional teaching method intervention. as a result of effective use of the constructivist teaching methods to teach the concept.

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Overview

This chapter summarizes the study's principal finding, conclusions based on the findings, recommendations for future educational policies and finally, suggestions for future research in this topic area were also examined.

5.1 Summary

The study used constructivist teaching approach to enhance the performance of Potsin T.I Ahmadiyya Senior High School students in solving quadratic equations by the graphical method. The research design used in this study was quasi-experimental non-equivalent group design with pre-test post-test. The target population was all SHS form two (2) students of Potsin T.I Ahmadiyya Senior High School. Convenient sampling technique was used to select the second-year students from the school for the study due to easy accessibility and proximity to the researcher. Purposive sampling technique was used to select the two intact classes for the study, one with a sample size of thirty-three (33) control group and the other with a sample size of twenty-three (23) experimental group, respectively. The researcher was in charge of the data collection.

Data was collected using a pre-test-post-test, as well as an interview guide, before and after the four-weeks treatments period. Students' overall performance was described using descriptive statistics (mean and standard deviation) and inferential statistics (independent sample t-test) was employed as statistical techniques with the help of the use of IBM SPSS Statistic 23 software to analyze the data at significant level of 0.05.

The research question 1 sought to find out the difficulties and errors SHS form two (2) students of Potsin T.I Ahmadiyya Senior High School make when solving quadratic equations by the graphical methods. Students' area of difficulties in solving quadratic equations by the graphical methods includes:

- Finding tables of values
- Plotting of points in the Cartesian plane
- Drawing of smooth curves
- Finding solution set of the graph
- Finding the equation of axis of line of symmetry
- Finding the solution set for the graph
- Finding the maximum or minimum point and value of the graph

The researcher took the participant through an intervention phase to help minimize students' errors and also help them overcome their difficulties in solving quadratic equations by the graphical method with an experiment in which one group was introduce to treatment with the constructivist approach and the other with the conventional approach to improve their performance in mathematics.

The intervention results revealed that most students from both groups showed some level of improvement in the post-test scores. However, those in the experimental group showed a statistically significant improvement in the mean scores of the post-test than their peers in the control group. In other words, students in the experimental group achieved higher in the post-test than their peers in the control group. This means that the two methods employed for the treatment contributed to student's performance. However, constructivist teaching approach was much effective and enhanced student's performance better than the conventional teaching methods of teaching the topic "solving quadratic equations by the graphical methods". It is therefore evidence that constructivist teaching approach has positive effect in improving the performance of students in solving quadratic equations by the graphical method compared to the conventional teaching method. It also suggests that, constructivist teaching approach is one of the most effective teaching and learning strategies mathematics teachers need to adopt in their classroom to enhance students' understanding and retention in learned mathematical concepts which could help improve students' performance in mathematics. Students responds from the interview indicated that, participants from the experimental group interviewed revealed that student support the view that the use of constructivist teaching approach in terms of its implementation and effectiveness in teaching mathematical concept is the best.

In summary, the findings from the study showed that constructivist approach of teaching changes the way students perceive mathematics subject, enhances students' conceptual understanding in mathematics, retention and contribute to their academic achievement. Again, the constructivist teaching approach employed in the treatment encouraged learning by teaching and teamwork among students. It ensures equity to all students, solving quadratic equations by graphical method skills, error correction as well as the ability to absorb concepts in a variety of ways, improves verbal presentation of work and communicate mathematical ideas to peers.

Analysis of students' performance in the post-test of the experimental group typically indicated an improved conceptual understanding of solving quadratic equations by the graphical methods as compared with students in the conventional group. This performance suggests that, there has been a significant reduction in learners' errors and difficulties in solving quadratic equations by the graphical methods with the experimental group as compared with the control group which is also one of the factors of poor performance of students in mathematics.

The observation made before and after the treatment of the experimental group and the responds from students interviewed revealed that student's perception of constructivist teaching methods used in teaching the topic "solving quadratic equations by the graphical methods" was positive.

5.2 Conclusion

The success of this study employing constructivist teaching approach reveals that, when a classroom teacher is committed to help a student to succeed in mathematics, he/she can change the learning climate by incorporating constructivism into the learning environment which will benefit majority of students academically. The test findings suggest that when students are given the opportunity to develop their own knowledge while being guided by a teacher, they will have little difficulty in learning mathematics. The constructivist approach should be part of classroom teachers' techniques of transferring knowledge to students since students learn better when they do things on their own, search for information, and study on their own under the guidance of a teacher.

The study further revealed that after students have been taught through the constructivist approach, students were more motivated to learn because students were able to overcome their shyness and interacted more actively in class. Students who were nervous at the begging of the class became confident after the treatment, made sense with the concept learnt, enjoyed different learning technique, and took ownership of their own learning process. Active participation of students in the teaching and learning process of solving quadratic equations by the graphical method had a contribution to the students' understanding of the concept. The instructions based on constructivist approach produces higher positive attitudes in mathematics as a subject and therefore, teachers must have in-depth knowledge in the use of this approach for effective teaching and learning and the understanding of all mathematics concepts.

5.3 Recommendation

In light of the above, the researcher would like to draw the following recommendations.

- Mathematics teachers should give learners ample opportunities for them to discover and construct their own knowledge rather than the learners absorbing knowledge from the teacher. It is critical for teachers to note that all knowledge is constructed hypothetically. No one constructs knowledge for the benefit of others. The knowledge constructed by learners themselves are more meaningful than that transmitted to them by the teacher or someone else.
- Mathematics instructors should recognize that learners come to the new lesson with prior knowledge that may contain gaps due to incorrect conceptions that are resistant to change and could result in learners' systematic errors and difficulties in teaching and learning of mathematics. Consequently, throughout instruction, teachers should provide learners with opportunity to recognize their errors and modify them in light of new evidence as well as support from a capable peer or the teacher.
- The value of knowledge is determined by how it is used. As a result of that, instruction should aim at improving students' ability to apply the mathematical concepts and principles they have learned to solve a given problem.
- Knowledge construction involves giving learners the ability to be in charge of their own learning. Teachers must act as facilitators of learning rather than

instructors and provide scaffolding for students as they create their own knowledge.

- Mathematics teaching should aim at encouraging instructional methods of teaching where the teacher provides opportunities for students to learn cooperatively in groups by sharing different views of ideas, interest, and skills. With this, members of the group have the opportunity for formal discussions, problem-solving activities, peer assessment and how to analyze problem from a variety of angle, communicate effectively with one another and solve problems on their own with support from their peers.
- Final assessment should include teacher observation of students at work and through students' exhibitions and portfolios, discussions, group and individual work. This will motivate students to actively participate in the teaching and learning process even though equal marks are generally given in group work, students should be aware that their lack of active participation in group work or project work could result to the award of lower marks for the individual. An awareness of this increases the level of participation by members.
- In order to ensure that pre-service teachers have acquired the necessary prerequisite knowledge to help them teach their learners effectively within the domain of constructivism by the time they go into the classroom, teacher training instructions should place emphasis on constructivist theories.
- Mathematics teacher educators should organize and create awareness among other teachers that traditional instruction is becoming less and less relevant to achieving the goals of Mathematics education in the present era. Mathematics teachers should be encouraged to implement the constructivist approach in their classroom instruction.

- Teaching of mathematics requires a shift from a teacher-centered approach to a student-centered approach at all level in our schools, the government should make a policy that will make the constructivist approach of teaching the primary teaching strategy for teaching mathematics in our schools.
- Finally, the government should make every effort to provide schools with the necessary teaching and learning resources needed to facilitate constructivist teaching approach. Availability of adequate teaching materials such as computers, graph boards, syllabus, graphing calculators and textbooks. Classroom environment and other infrastructure will motivate and encourage teachers to choose and adopt constructivist teaching approach for classroom instruction.

5.4 Suggestion for Future Research

- The study was carried out in a grade B school in the Gomoa East District in the central region of Ghana. This study recommends for similar study conducted in different schools in other districts in Ghana to provide a generalization for Ghana, especially students with higher learning skills in grade 'A' school's achievement with the constructivist teaching approach compared with those of learning abilities in grade B, C or D schools to see if it will be effective for both cases.
- Again, the study investigated the use of constructivist approach to enhance students' performance in solving quadratic equations by the graphical method, but it did not delve deep into comparing the effect of using other constructivist approach such as exploration, discovery, problem-solving, small group work, reflective tutoring, and peer learning and order traditional teaching methods

such as lecture and direct instructions, seatwork and listening and observations methods of teaching. However, the researcher recommends that a comprehensive study should be conducted to find the relationship between the constructivist approaches mentioned above and other traditional approach as well.

- The study focused on using constructivist approach to enhance students' performance in solving quadratic equations by the graphical method alone as captured within the mathematics syllabus, further studies can be carried out for other mathematics topics and other subjects at the SHS to investigate the effectiveness of the constructivist approach

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APPENDICES

APPENDIX A

TREATMENT SCHEDULE / SCHEME OF WORK

Lesson	Procedure	Content Covered (Experimental group/Control group)	Duration Hours/Minutes
Lesson 1	Treatment	Self-Introductory Orientation Definition of quadratic function. Drawing table of values	60
Lesson 2		Choosing correct scales, plotting of points in the Cartesian plane. Drawing graph of quadratic function.	60

Lesson 3		Interpretation of quadratic function (solution sets, equation of line of symmetry, minimum and maximum value or points)	60
Lesson 4		Interpretation of quadratic function (range of value of x as y increases or decreases, range of value of x as $y > 0$ or $y \leq 0$) Gradient of a curve	60

APPENDIX B

LESSON PLAN FOR THE EXPERIMENTAL GROUP-CONSTRUCTIVIST TEACHING METHOD

LESSON: One (1)

SUBJECT: Core Mathematics **YEAR:** 2 **DURATION:** 60 minutes

TOPIC: Solving Quadratic Equation by the Graphical Methods

SUB- TOPICS: Definition of quadratic function. Drawing table of values

SPECIFIC OBJECTIVES: By the end of the lesson, the student will be able to:

- define quadratic function
- draw table of value

RPK: **(i)** Students have seen bow and arrow.

(ii) Students have witnessed a volley ball match held in their school

(iii) Students can factorize quadratic expressions

INTRODUCTION: Use question and answer method to revise students' RPK.

QUESTION:

1. What is the shape of the bow?
2. What is the shape of the Adomi Bridge?
3. What shape is formed when a volleyball player decides to serve the ball?
4. What is the shape of a satellite dish? etc.

Are they curves or straight lines?

EXPECTED ANSWER:

They are curves

QUESTION:

i. Factorize the following quadratic expressions completely

(a) $x^2 + 9x + 14$

(b) $-x^2 - 6x + 7$

EXPECTED ANSWERS:

(a) $(x + 2)(x + 7)$

(b) $(x - 1)(x + 7)$

TEACHER AND LEARNER ACTIVITY

WHOLE CLASS DISCUSSION

Activity 1

Show pictures of shapes that has either $\cup -shape\ or\ \cap -shape$

Ask students to brainstorm to come out with the definition of quadratic function.

EXPECTED ANSWER:

A quadratic function is a second order polynomial function in a single variable of the form

$f: x \rightarrow\ x^2 + bx + c, where\ a, b, c\ are\ real\ numbers\ and\ a \neq 0$

Activity 2

Assist students to build table of values with a given relation.

EXAMPLE: Draw a table of values for the relation $y = 2x^2 + x - 3$ for values of x from -3 to 3

EXPECTED ANSWER

x	-3	-2	-1	0	1	2	3
$2x^2$	18	7	0	-3	2	8	18
x	-3	-2	-1	0	1	2	3
-3	-3	-3	-3	-3	-3	-3	-3
y	12	2	-4	-6	0	7	18

GROUP WORK

Put students into groups of four and each group appoint a leader. Provide students with graph sheets, rules, erasers and pencils

Give students a relation with its interval to draw a table of values. Go round, supervise students work, and give help to those with difficulty.

INDEPENDENT PRACTICE

Discuses with students their common errors identified during supervision. Let student practice some questions individually for independent practice. Assess the whole class by using the total scores of each group to declare the winner for the day.

CLOSURE: Go through the lesson through questioning. Ask students to briefly tell whatever they have learnt and end the lesson by giving students excise, mark, correct mistakes, and help those with difficulty.

Remind the students to read on the next topic (choosing correct scales, plotting points in the Cartesian plane, drawing graph of quadratic function)

CORE POINT: Defining quadratic function.

-Drawing table of values

REFERENCES: Concise Core Mathematics for Senior High Schools, Page 213-235

Ghana Senior Secondary School Mathematics Book 1, Page 260-270

Teaching Syllabus for Core Mathematics (2010), page 36-37

TEACHING LEARNING MATERIAL (TLM): Graph board, meter rule, marker, pencil, eraser graph books, Core Mathematics SHS Syllabus, SHS Core Mathematics Teachers' Guide, SHS Core Mathematics Text Book 2

EVALUATION: Use questions on the topic from students' work book to evaluate the lesson.

REMARKS: The lesson was successfully taught. About 95% grasp the concept

LESSON: TWO (2)

SUBJECT: Core Mathematics **YEAR:** 2 **DURATION:** 60 minutes

TOPIC: Solving Quadratic Equation by the Graphical Methods

SUB- TOPICS: - Choosing correct scales

-Plotting points in the Cartesian plane

-Drawing graph of quadratic function

SPECIFIC OBJECTIVES: By the end of the lesson, the student will be able to:

-choose correct scale

-plot points in the Cartesian plane of a given quadratic function.

-draw graph of quadratic function

RPK: Students can: (1) identify functions that are quadratic.

(2) draw table of values of a given relation with its interval.

INTRODUCTION: Use question and answer method to revise students' RPK.

1. Which of the following function is / are quadratic function?

a. $y = \frac{2}{3}x^2 + 5$

b. $y = 2x^3 + x + 7$

c. $y = 3x + 1$

d. $y = 12x^2 - x - 1$

EXPECTED ANSWER:

Questions a and d are quadratic functions

2. Draw table of values for the relation $y = x^2 + 2x - 3$ for the interval $-4 \leq x \geq 2$.

EXPECTED ANSWER

x	-4	-3	-2	-1	0	1	2
x^2	16	9	4	1	0	1	4
$2x$	-8	-6	-4	-2	0	2	4
-3	-3	-3	-3	-3	-3	-3	-3
y	5	0	-3	-4	-3	0	5

TEACHER AND LEARNER ACTIVITY

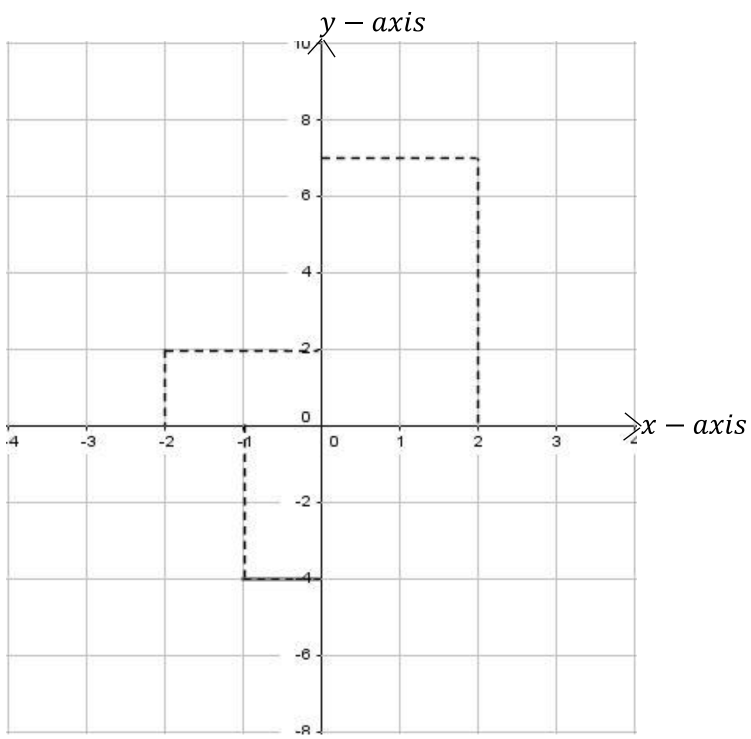
WHOLE CLASS DISCUSSION

Activity 1

Assist students on how to choose a correct scale and plot points in the Cartesian plane of a given quadratic relation. From the table of values drawn ask students in their various group to discuss among themselves to come out with appropriate scale for the relation.

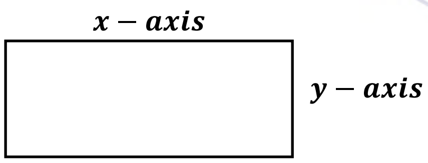
Choosing Correct Scale

EXAMPLE: using the set of ordered pairs for $y = 2x^2 + x - 3$ $\{(-3.12), (-2,3), (-1,2), (0, -3), \ (1,0), (2,7), (3,18)\}$. Vertically, the values are $\{-3, 0,2.3,7,12, 18\}$ therefore a scale of $1 square\ to\ 2\ unit$ is best appropriate. That is, $(, -4, -2, \ 0, \ 2, 4, 6, 8, 10, 12, 16, 18)$. Horizontally, the values are $\{-3, -2, -1,0,1,2,3\}$ therefore a scale of $1 square\ to\ 1 unit$ is best appropriate.



Activity 2

Guide students to locate and draw points in the Cartesian plane. Example, to locate (2 ,7) Since both points are positive, then they can be found in quadrant 1. Using the shape of a rectangle, we have



Plotting points in the Cartesian plane

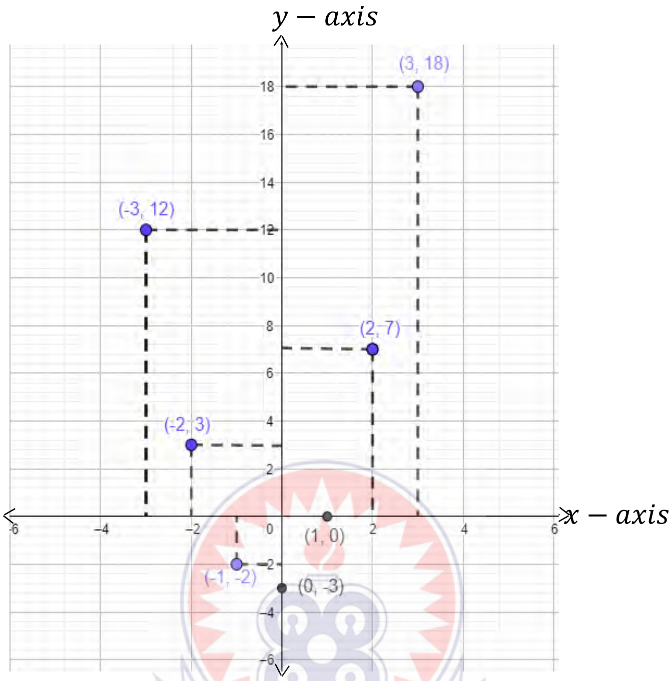
Steps to locate the points

1. Starting from the origin that is o.
2. Move two units right and seven unit up
3. At the origin, move seven (7) units up and two (2) unit's rights. Their meeting points is the point (2,7). This gives a rectangular shape that has its length equal to two (2) and breath equal to seven (7).

Activity 3

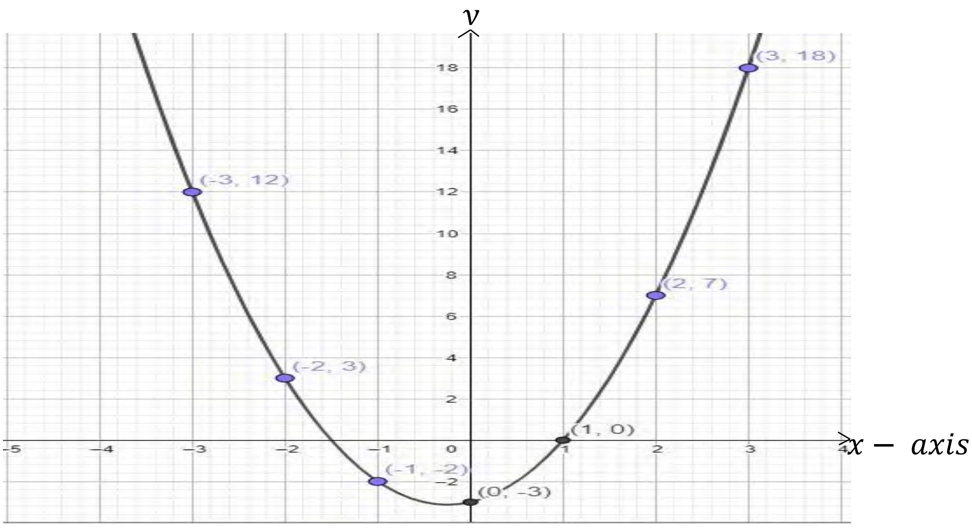
Ask students in their various groups to use the table of values drawn for the relation $y = x^2 + 2x - 3$ to plot points in the Cartesian plane. Go round to help those facing challenges with locating and plotting of the points.

EXPECTED ANSWER:



With the point plotted, ask students to join the plotted points to form a smooth curve. Let the students know that, graphs of quadratic curves are smooth cup-shaped and symmetric, with no sharp point or kink in them.

Drawing graph of quadratic function



GROUP WORK

Give the group a relation to draw a table of values, choose a correct scale, plot the points in the Cartesian plane and draw the graph for the relation. Go round, supervise students work, and correct them when necessary.

EXAMPLE: Draw table of values for the relation $y = -x^2 + 4$ for the interval $-3 \leq x \geq 3$. Choose a correct scale, plot the points in the Cartesian plane and draw the graph for the relation.

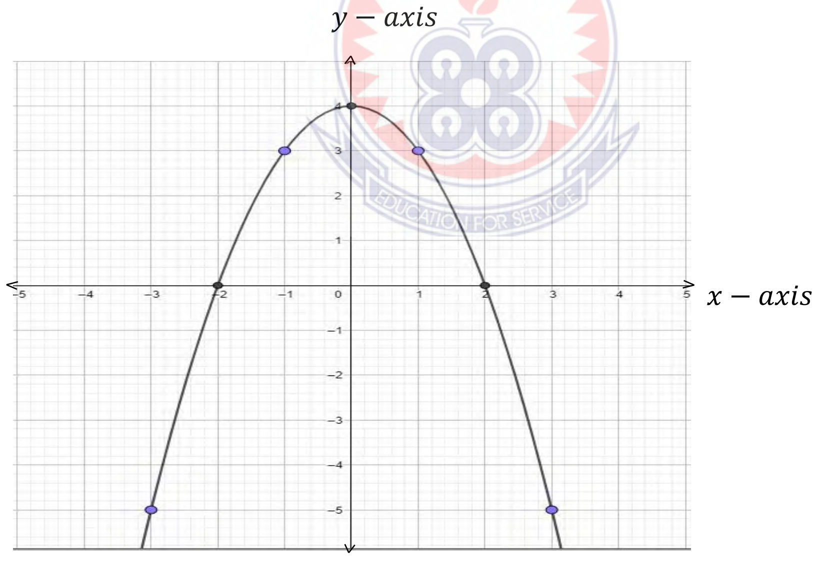
EXPECTED ANSWER

TABLE OF VALUES

x	-3	-2	-1	0	1	2	3
$-x^2$	-9	-4	-1	0	-1	-4	-9
4	4	4	4	4	4	4	4
y	-5	0	3	4	3	0	-5

Scale: $1cm to\ 1unit$ on both axes.

Graph of the relation $y = -x^2 + 4$



INDEPENDENT PRACTICE

Discuses with students their common errors identified during supervision. Let student practice some questions individually for independent practice. Assess the whole class by using the total scores of each group to declare the winner for the day.

CONCLUSION: Go through the lesson through questioning. Let students share with their peers what they have learnt for the day and end the lesson by giving students exercise, mark, and correct mistakes and help those with difficulty.

Remind students to read on the next topic (interpretation of quadratic function)

CORE POINT: -choosing correct scale

-plotting points in the Cartesian plane of a given quadratic function

-drawing graph of quadratic function.

REFERENCES: Concise Core Mathematics for Senior High Schools, Page 213-235

Ghana Senior Secondary School Mathematics Book 1, Page 260-270

Teaching Syllabus for Core Mathematics (2010), page 36-37

TEACHING LEARNING MATERIAL (TLM): Graph board, meter rule, marker, pencil, eraser graph books, Core Mathematics SHS Syllabus, SHS Core Mathematics Teachers' Guide, SHS Core Mathematics Text Book 2

EVALUATION: Use questions on the topic from students' work book to evaluate the lesson.

REMARKS: The lesson was successfully taught. About 85% grasp the concept.

LESSON: three (3)

SUBJECT: Core Mathematics **YEAR:** 2 **DURATION:** 60 minutes

TOPIC: Solving Quadratic Equation by the Graphical Methods

SUB-TOPIC: Interpretation of quadratic function (solution sets from graph, equation of line of symmetry and minimum and maximum value or points from graph)

SPECIFIC OBJECTIVES: By the end of the lesson, the student will be able to:

-find the solution sets of a quadratic relation from graph

- identify the line of symmetry and write its equation

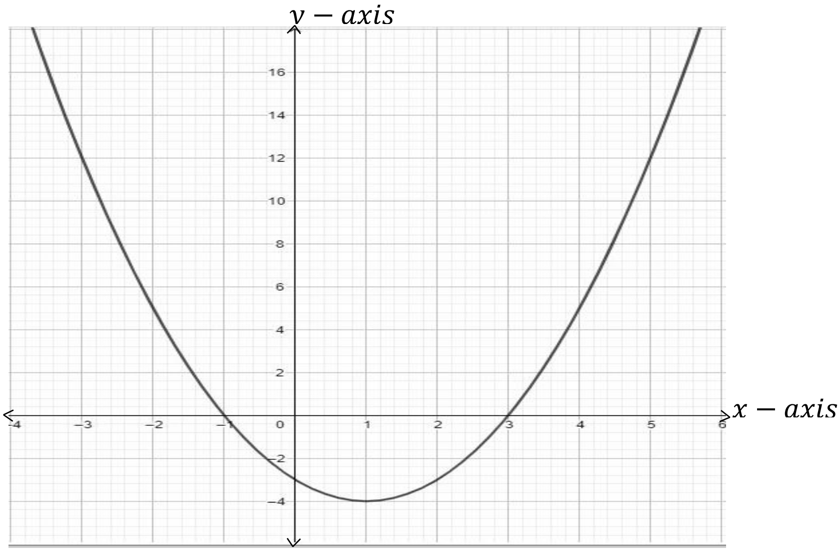
-find the minimum and maximum value or points from graph

RPK: Students can draw graph for a given relation.

INTRODUCTION: Use question and answer method to revise students' RPK

QUESTION: Draw a graph for the relation $y = x^2 - 2x - 3$ in the interval $-4 \leq x \geq 6$.

EXPECTED ANSWER:



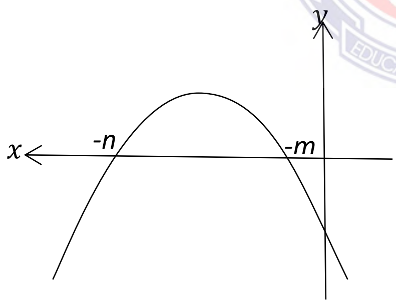
TEACHER AND LEARNER ACTIVITY

WHOLE CLASS DISCUSSION

Activity 1

Assist students to find the truth sets of a quadratic equation from a graph.

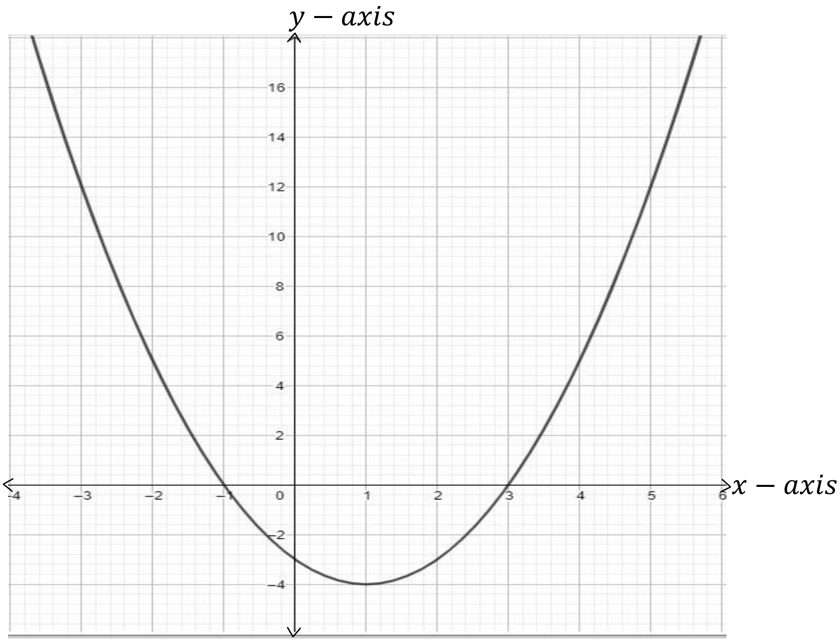
Finding solution sets from graph ($y = ax^2 + bx + c$)



The solution set of $y = ax^2 + bx + c$ is $\{x: x = -m, -n\}$, that is where the graph cuts the $x - axis$.

Ask students to read the solution set of the relation $y = x^2 - 2x - 3$ from the graph they have drawn.

EXPECTED ANSWER:



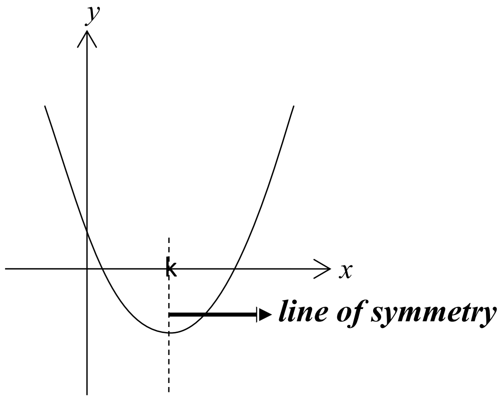
The solution set of the relation $y = x^2 - 2x - 3$ from the graph is $\{x: x = -1, 3\}$

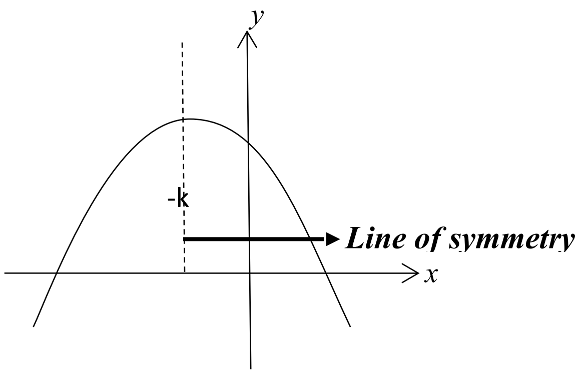
Activity 2

Assist students to establish that the quadratic graph is symmetrical about a vertical line and write its' equation as $x = k$. Where k is a real number?

Identifying the line of symmetry and writing its' equation

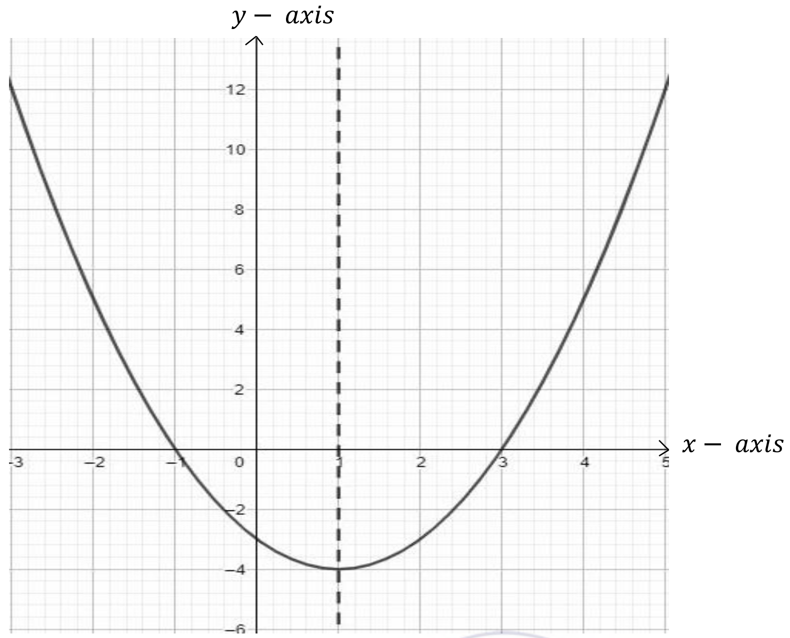
The line of symmetry passes through the turning point or the vertex. It is parallel to the $y-axis$





From the graph, the equation of axis of line of symmetry is $x = a$ and $x = -b$. Ask students to write the equation of axis of line of symmetry for the relation $y = x^2 - 2x - 3$ from the graph they have drawn.

EXPECTED ANSWER:

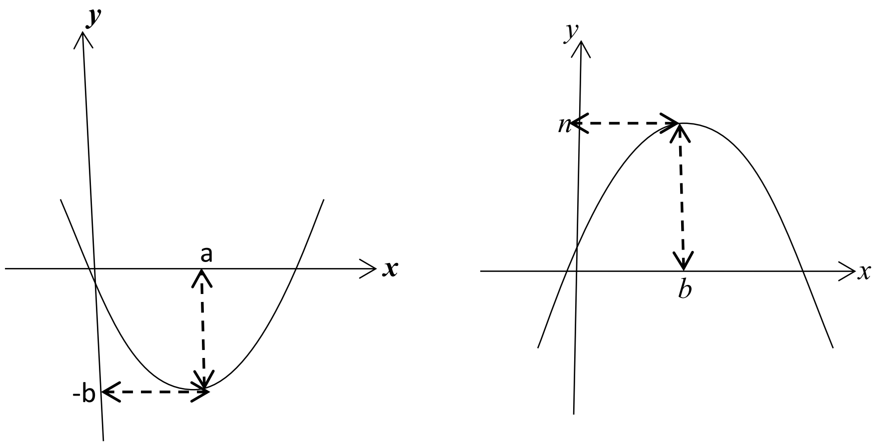


The equation of axis of line of symmetry from the graph is $x = 1$

Activity 3

Guide students to find the minimum and maximum value or points from graph and state the coordinate of the points where these value or points occur. Assist students to establish that the minimum and maximum value or points occur at the turning point of the graph.

Finding the minimum and maximum value or points from the graph

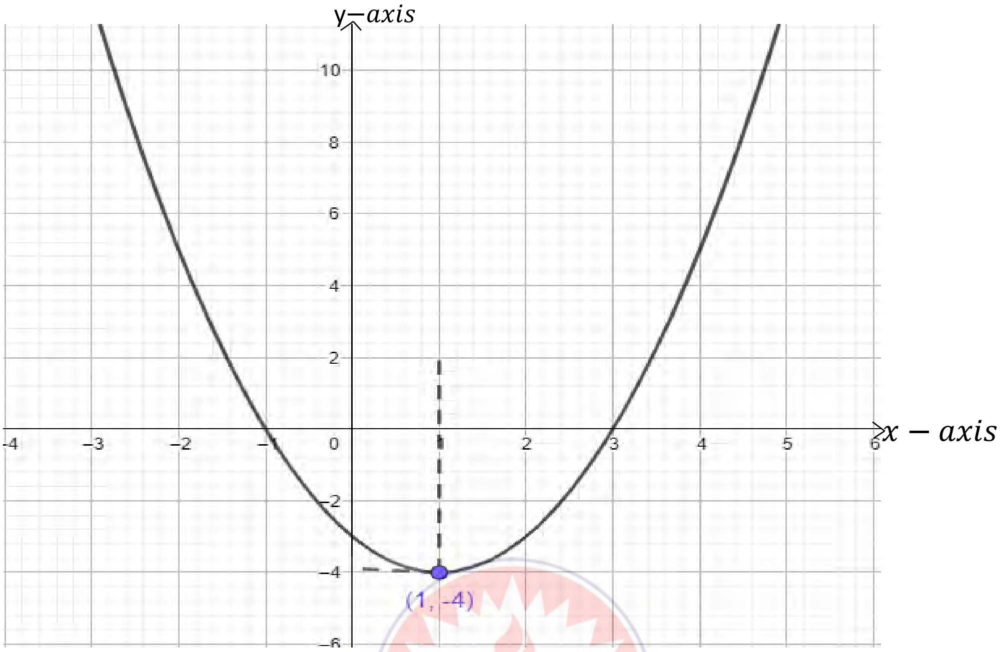


The minimum value of y is $-b$ and the minimum point is $(a, -b)$ and the maximum value of y is b and the greatest point is (b, n)

Ask students to read the minimum and maximum value or points for the relation

$y = x^2 - 2x - 3$ from the graph they have drawn.

EXPECTED ANSWER



Minimum point of the graph occurs at $(1, -4)$

Minimum value of the graph occurs at $y = -4$

GROUP WORK

Give the group a relation to draw a table of values, choose a correct scale, plot the points in the Cartesian plane and draw the graph for the relation. Ask the students to use the graph to find the solution sets of relation, the equation of the line of axis of symmetry of the graph and the minimum or maximum value or points from graph. Go round, supervise students work, and correct them when necessary.

EXAMPLE: Draw table of values for the relation $y = -3x^2 + 6x + 10$ for the interval $-3 \leq x \geq 5$. Choose a correct scale, plot the points in the Cartesian Plane and draw the graph for the relation. Use the graph to find

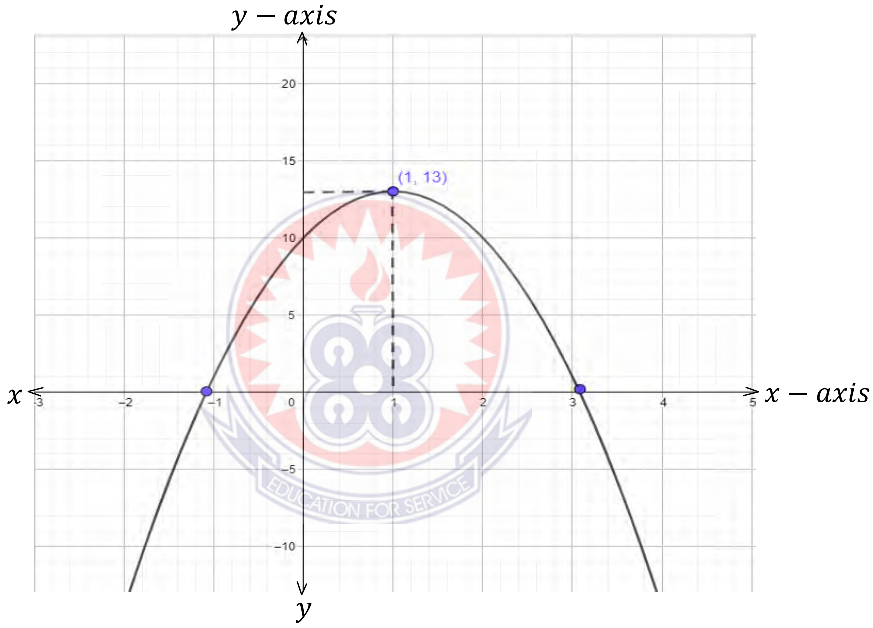
I. the solution sets of the relation $y = -3x^2 + 6x + 10$.
II. the equation of the axis of the line of symmetry of the graph.
III. find the maximum value and point of the graph.

EXPECTED ANSWER:

x	-3	-2	-1	0	1	2	3	4	5
$-3x^2$	-27	-12	-3	0	-3	-12	-27	-48	-75
$6x$	-18	-12	-2	0	6	12	18	24	30
10	10	10	10	10	10	10	10	10	10
y	-35	-14	1	10	13	10	1	-14	-25

Scale: 1cm to 1unit the on x-axis 1cm to 5unit on the y-axis

Graph of the relation $y = -3x^2 + 6x + 10$



I. The solution sets of the graph is $(x: x = -1.08, 3.08)$

II. the equation of the axis of the line of symmetry of the graph $x = 1$

III. the maximum value is $y = 13$

IV. the maximum point of the graph is $(1,13)$

INDEPENDENT PRACTICE

Discuses with students their common errors identified during supervision. Let student practice some questions individually for independent practice. Assess the whole class by using the total scores of each group to declare the winner for the day.

CONCLUSION: Go through the lesson through questioning. Let students share with their peers what they have learnt for the day and end the lesson by giving students exercise, mark, and correct mistakes and help those with difficulty.

Remind students to read on the next topic interpretation of quadratic function (Finding the range of value of x as y increases or decreases, range of value of x as $y > 0$ or $y < 0$. Finding the gradient of a curve).

CORE POINTS: finding solution sets of a quadratic relation from graph

- identifying the line of symmetry and writing its equation
- finding the minimum and maximum value or points from graph

REFERENCES: Concise Core Mathematics for Senior High Schools, Page 213-235
Ghana Senior Secondary School Mathematics Book 1, Page 260-270
Teaching Syllabus for Core Mathematics (2010), page 36-37

TEACHING LEARNING MATERIAL (TLM): Graph board, meter rule, marker, pencil, eraser graph books, Core Mathematics SHS Syllabus, SHS Core Mathematics Teachers' Guide, SHS Core Mathematics Text Book 2

EVALUATION: Use questions on the topic from students' work book to evaluate the lesson.

REMARKS: The lesson was successfully taught. About 80% grasp the concept.

LESSON: four (4)

SUBJECT: Core Mathematics **YEAR:** 2 **DURATION:** 60 minutes

TOPIC: Solving Quadratic Equation by the Graphical Methods

SUB-TOPICS: Interpretation of quadratic function (range of value of x as y increases or decreases, range of values of x as $y > 0$ or $y < 0$, gradient of a curve)

SPECIFIC OBJECTIVES: By the end of the lesson, the student will be able to:

-find the range of values of x as y increases or decreases.

-find the range of values of x as $y > 0$ or $y < 0$.

-find the gradient of the curve.

RPK: students can draw graph of a relation and find the solution set, the equation of the axis of line of symmetry and the minimum or maximum value or point from the graph.

INTRODUCTION: Use question and answer method to revise students' RPK.

QUESTION: Draw table of values for the relation $y = x^2 - 2x - 8$ for the interval$-2 \leq x \geq 4$. Choose a correct scale, plot the points in the Cartesian plane and draw the graph for the relation. Use the graph to find

i. the solution sets of $y = x^2 - 2x - 8$.

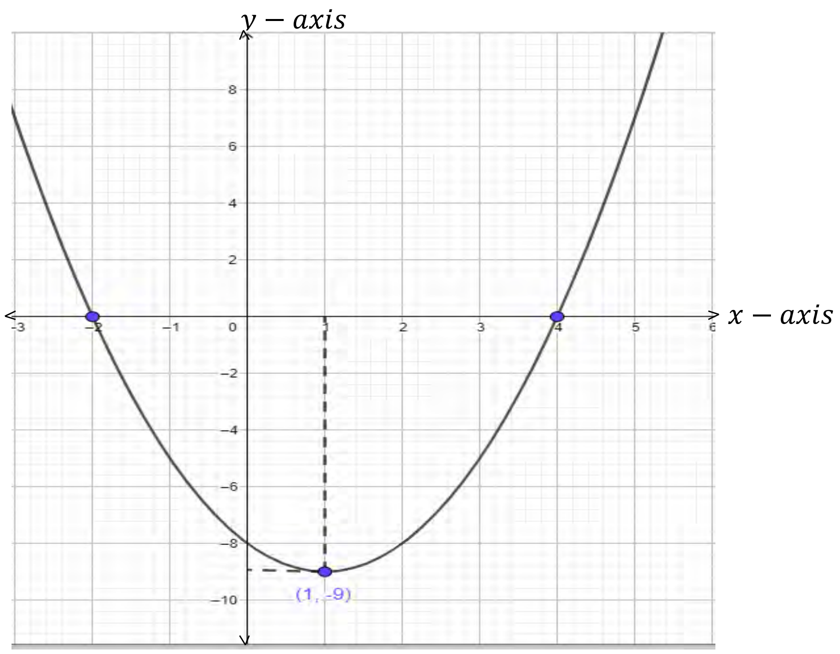
ii. the equation of the axis of the line of symmetry.

iii. find the minimum value and point of the graph.

EXPECTED ANSWER:
Table of values:

x	-2	-1	0	1	2	3	4
x^2	4	1	0	1	4	9	16
$-2x$	4	2	0	-2	-4	-6	-8
-8	-8	-8	-8	-8	-8	-8	-8
y	0	-5	-8	-9	-8	-5	0

Graph of the relation $y = x^2 - 2x - 8$



i. the solution sets of $y = x^2 - 2x - 8$ is (-2,4)

ii. the equation of the axis of the line of symmetry is $x = 1$

iii. find the minimum value is $y = -9$ and minimum point of the graph is $(1, -9)$

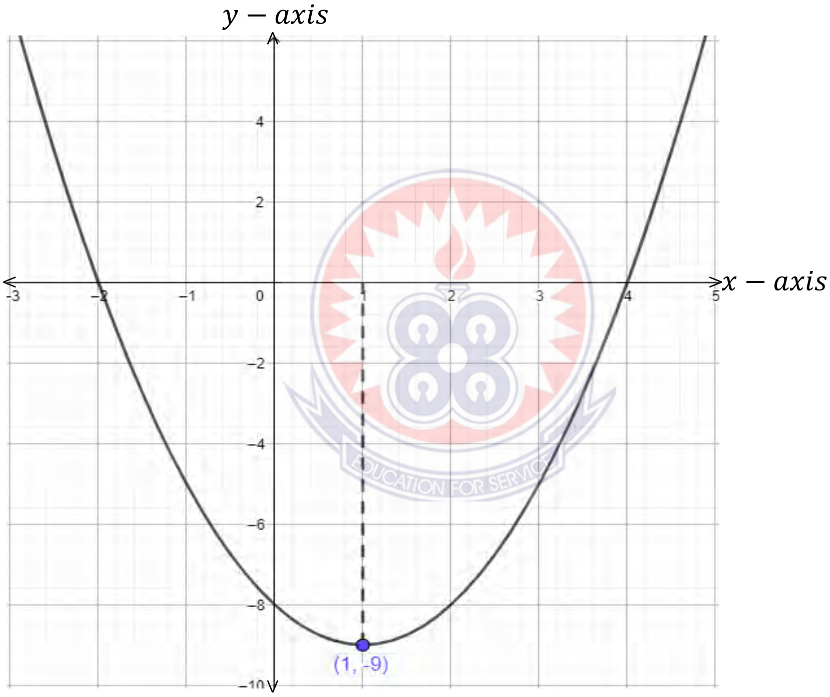
TEACHER AND LEARNER ACTIVITY

WHOLE CLASS DISCUSSION

Activity 1

Let students in their various groups discuss and come out with their own finding of the range of values of x for which the graph is increasing or decreasing for the relation $y = x^2 - 2x - 8$ from the graph they have drawn

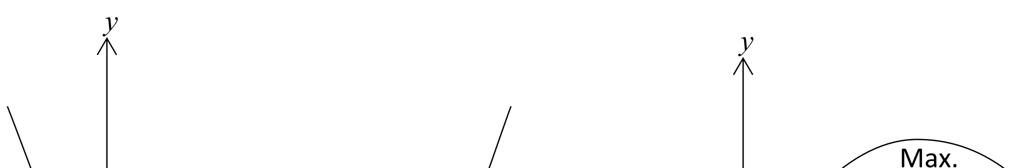
EXPECTED ANSWER:



The range of values of x for which y decreases is $x < 1$

The range of values of x for which y increases is: $x > 1$

Finding the range of values of x as y increases or decreases



The range of values of x for which y decreases is $x < b$

The range of values of x for which y increases is: $x > b$

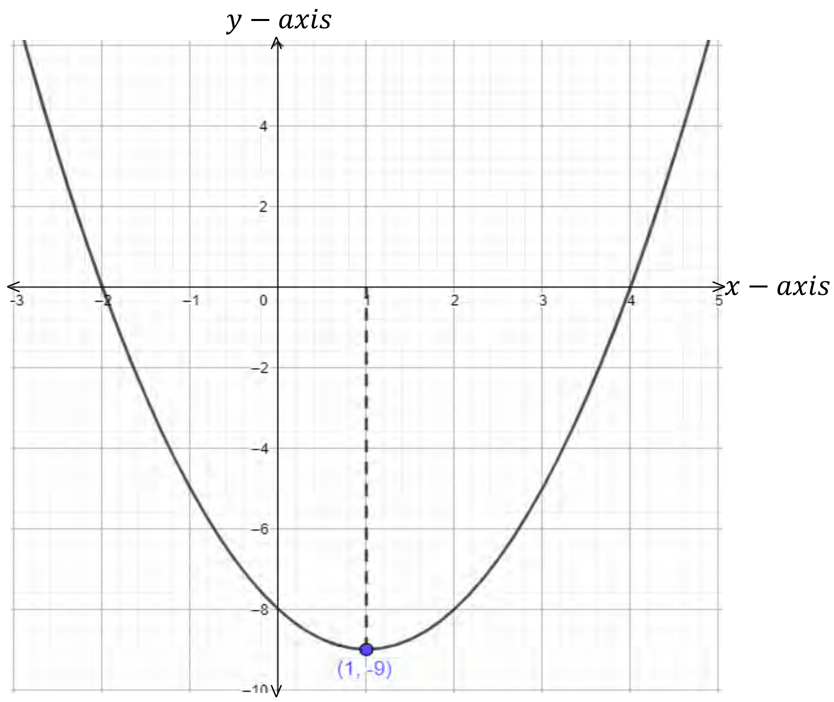
The range of values of x for which y increases is: $x < c$

The range of values of x for which y decreases is $x > c$

Activity 2

Let students in their various groups discuss and come out with their own finding of range of values of x as $y > 0$ or $y \leq 0$ for the relation $y = x^2 - 2x - 8$ from the graph they have drawn.

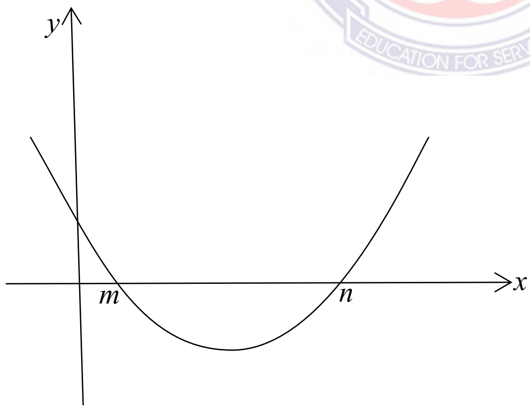
EXPECTED ANSWER:

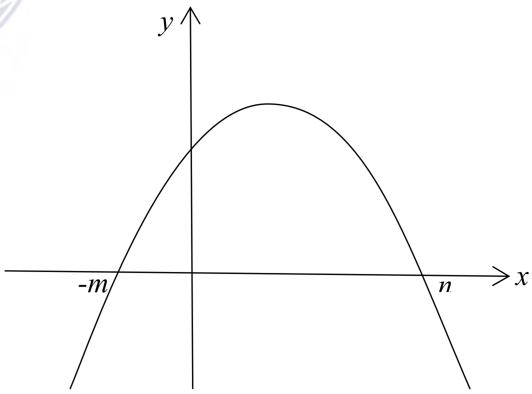


The range of values of x as $y > 0$ is $-2 < x$ or $4 > x$

The range of values of x as $y \leq 0$ is $-2 \leq x \leq 4$

Finding the value of x for which y ≤ 0 and y > 0 .





the value of x for which y ≤ 0 $is\ m \leq x \leq n$

the value of x for which y > 0 is $m > x$ or $x > n$

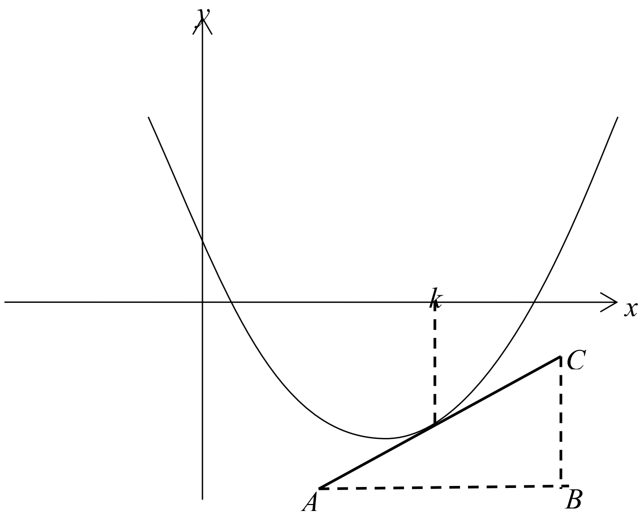
the value of x for which y < 0 is $-m > x$ or $x > n$

the value of x for which y ≥ 0 is $-m \leq x \leq n$

Activity 3

Demonstrate to the students how to find the gradient of the curve

Finding the gradient of a curve at $x = k$



Steps to follow:

Draw two (2) perpendicular line at the point $x = k$

Draw a line of tangent through k, dividing the squares above and below equally.

Use the line of tangent drawn to form a right-angled triangle.

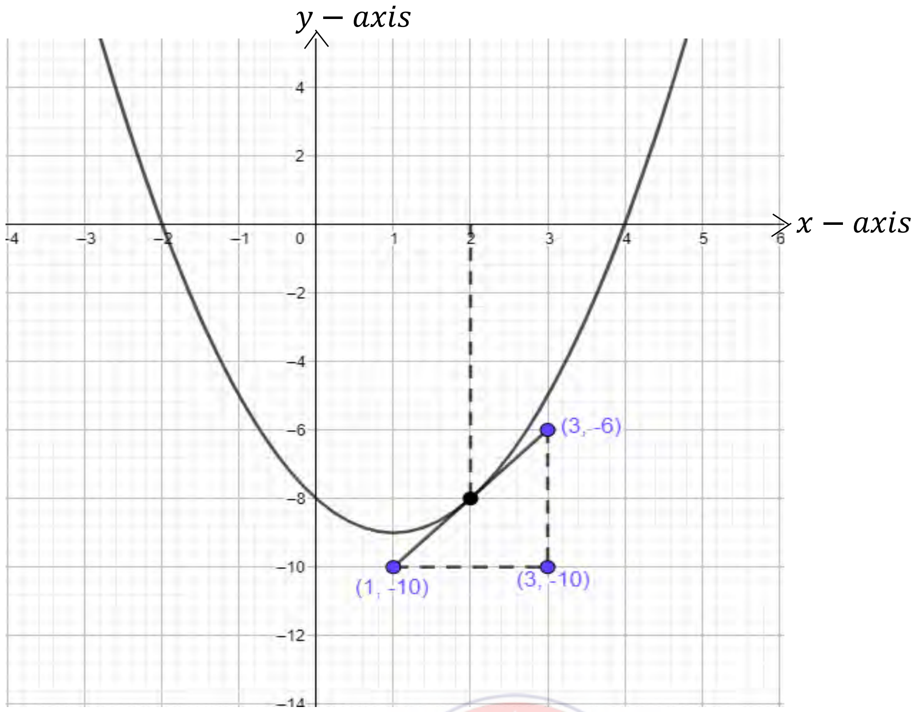
Use the slope or gradient formula below to find the gradient for the slop.

Gradient or slope: m= $\frac{BC}{AB} = \frac{change\ in\ the\ vertical\ axis}{change\ in\ the\ horizontal\ axis}$

NOTE: this method only gives an approximate answer. The better your graph is, the closer your answer will be the correct answer.

Give students the opportunity to discuss and find the gradient of the curve for the relation $y = x^2 - 2x - 8$ they have drawn.

EXPECTED ANSWER



Gradient or slope m= $\frac{\nabla y}{\nabla x} = \frac{-6-(-10)}{1-3} = -\frac{4}{2} =$ -2

Give the group a relation to draw a table of values, choose a correct scale, plot the points in the Cartesian plane and draw the graph for the relation. Ask students to use the graph to find the solution sets of relation, the equation of the line of axis of symmetry of the graph, the minimum or maximum value or points, find the range of values of x as y increases or decreases, range of values of x as $y > 0$ or $y < 0$ and find the gradient of the curve from the graph. Go round, supervise students work, and correct them when necessary.

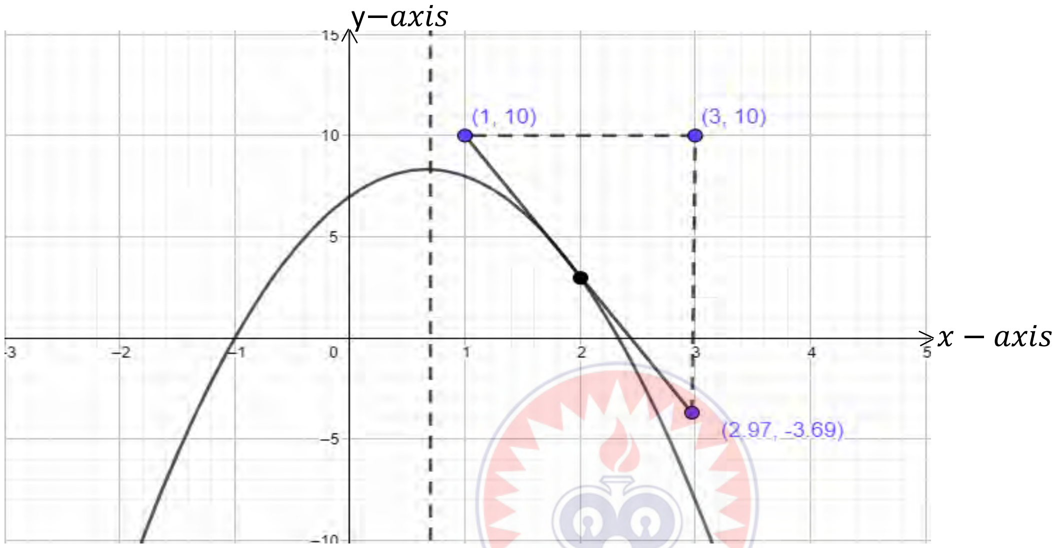
Example: Draw table of values for the relation $y = -3x^2 + 4x + 7$ or the interval $-3 \leq x \geq 4$. Using a scale of $2cm$ to $2unit$ on the $x - axis$ and $1cm$ to $5unit$ on the $y - axis$, draw the graph for the relation. Use the graph to find:

I. the solution sets of the relation $y = -3x^2 + 4x + 7$.
II. the equation of the axis of the line of symmetry of the graph.
III. find the maximum value and point of the graph.
IV. find the range of value of x as y is increasing and decreasing.
V. Finding the value of x for which $y \leq 0$ and $y > 0$.
VI. find the gradient of the curve.

EXPECTED ANSWER:

x	-3	-2	-1	0	1	2	3	4
$-3x^2$	-27	-12	-3	0	-3	-12	-27	-48
$4x$	-12	-8	-4	0	4	8	12	16
7	7	7	7	7	7	7	7	7
y	-32	-13	0	7	8	3	-8	-25

Graph of the relation $y = -3x^2 + 4x + 7$



the solution sets of the relation $y = -3x^2 + 4x + 7$ is $\{x: x = -1, 2.3\}$

the equation of the axis of the line of symmetry of the graph is $x = 0.7$

the maximum value of the graph is $y = 8.33$

the maximum point of the graph is (0.7, 8.33)

the range of value of x as y is increasing is $x < 0.7$

the range of value of x as y is decreasing is $x > 0.7$

the value of x for which $y \geq 0$ is $-1 \leq x \leq 2.3$

the value of x for which $y < 0$ is $x < -1$ *or* $x > 2.3$

the gradient of the curve is:

Gradient or slope m= $\frac{\nabla y}{\nabla x} = \frac{-3.69-10}{3-1} = \frac{-13.69}{2}$ = -6.845

INDEPENDENT PRACTICE

Discuses with students their common errors identified during supervision. Let student practice some questions individually for independent practice. Assess the whole class by using the total scores of each group to declare the winner for the day.

Conclusion: Go through the lesson through questioning. Let students share with their peers what they have learnt for the day and end the lesson by giving students exercise, mark, and correct mistakes and help those with difficulty.

CORE POINTS: -finding the range of values of x as y increases or decreases

-range of values of x as $y > 0$ or $y < 0$.

- finding the gradient of the curve.

REFERENCES: Concise Core Mathematics for Senior High Schools, Page 213-235

Ghana Senior Secondary School Mathematics Book 1, Page 260-270

Teaching Syllabus for Core Mathematics (2010), page 36-37

TEACHING LEARNING MATERIAL (TLM): Graph board, meter rule, marker, pencil, eraser graph books, Core Mathematics SHS Syllabus, SHS Core Mathematics Teachers' Guide, SHS Core Mathematics Text Book 2

EVALUATION: Use questions on the topic from students' work book to evaluate the lesson.

REMARKS: The lesson was successfully taught. About 95% grasp the concept.

APPENDIX C

LESSON PLAN FOR THE CONTROL GROUP-CONVENTIONAL TEACHING METHOD

LESSON: ONE (1)

SUBJECT: Core Mathematics **YEAR:** 2 **DURATION:** 60 minutes

TOPIC: Solving Quadratic Equations by the Graphical Method

SUB -TOPICS: Definition of quadratic function.

-Drawing table of values

SPECIFIC OBJECTIVES: By the end of the lesson, the student will be able to:

- define quadratic function
- draw table of value

RPK: Students can factorize quadratic expressions completely

INTRODUCTION: Use question and answer method to revise students' RPK.

QUESTION:

Factorize the expression completely

(a) $x^2 + 9x + 14$

(b) $-x^2 - 6x + 7$

TEACHER AND LEARNER ACTIVITY

WHOLE CLASS DISCUSSION

Activity 1: Ask students to brainstorm to come out with the definition of quadratic function.

Activity 2: Assist students to build table of values with a given relation.

Activity 3: Give students a relation with its interval to draw a table of values

Activity 4: Let students practice how to draw table of value for a given relation

CLOSURE: Go through the lesson through questioning. End the lesson by giving students excise, mark, correct mistakes.

Remind the students to read on the next topic (choosing correct scales, plotting points in the Cartesian plane, drawing graph of quadratic function)

CORE POINTS: Defining quadratic function.

-Drawing table of values

REFERENCES: Concise Core Mathematics for Senior High Schools, Page 213-235

Ghana Senior Secondary School Mathematics Book 1, Page 260-270

Teaching Syllabus for Core Mathematics (2010), page 36-37

TEACHING LEARNING MATERIAL (TLM): Graph board, meter rule, marker, pencil, eraser graph books, Core Mathematics SHS Syllabus, SHS Core Mathematics Teachers' Guide, SHS Core Mathematics Text Book 2

EVALUATION: Use questions on the topic from students' work book to evaluate the lesson.

REMARKS: The lesson was successfully taught. About 65% grasp the concept

LESSON: TWO (2)

SUBJECT: Core Mathematics **YEAR:** 2 **DURATION:** 60 minutes

TOPIC: Solving Quadratic Equations by the Graphical Method

SUB- TOPICS: - Choosing correct scales

-Plotting points in the Cartesian plane

-Drawing graph of quadratic function

SPECIFIC OBJECTIVES: By the end of the lesson, the student will be able to:

- -choose correct scale
- -plot points in the Cartesian plane of a given quadratic function.
- -draw graph of quadratic function

RPK: Students can: (1) identify functions that are quadratic.

(2) draw table of values of a given relation with its interval.

INTRODUCTION: Use question and answer method to revise students' RPK.

1. Which of the following function is / are quadratic function?

a) $y = \frac{2}{3}x^2 + 5$

b) $y = 2x^3 + x + 7$

c) $y = 3x + 1$

d) $y = 12x^2 - x - 1$

2. Draw table of values for the relation $y = x^2 + 2x - 3$ for the interval $-4 \leq x \geq 2$.

TEACHER AND LEARNER ACTIVITY

WHOLE CLASS DISCUSSION

Activity I: Assist students on how to choose a correct scale and plot points in the Cartesian plane of a given quadratic relation.

Activity 2: Guide students to locate and draw points in the Cartesian plane.

Activity 3: Use varying examples to help students to choose a correct scale and plot points in the Cartesian plane of a given quadratic relation, locate and draw points in the Cartesian plane.

CONCLUSION: Go through the lesson through questioning. End the lesson by giving students exercise, mark, and correct mistakes.

Remind students to read on the next topic (interpretation of quadratic function)

CORE POINTS: -choosing correct scale

-plotting points in the Cartesian plane of a given quadratic function.

-drawing graph of quadratic function.

REFERENCES: Concise Core Mathematics for Senior High Schools, Page 213-235

Ghana Senior Secondary School Mathematics Book 1, Page 260-270

Teaching Syllabus for Core Mathematics (2010), page 36-37

TEACHING LEARNING MATERIAL (TLM): Graph board, meter rule, marker, pencil, eraser graph books, Core Mathematics SHS Syllabus, SHS Core Mathematics Teachers' Guide, SHS Core Mathematics Text Book 2

EVALUATION: Use questions on the topic from students' work book to evaluate the lesson.

REMARKS: The lesson was successfully taught. About 60% grasp the concept.

LESSON: THREE (3)

SUBJECT: Core Mathematics **YEAR:** 2 **DURATION:** 60 minutes

TOPIC: Solving Quadratic Equations by the Graphical Method

SUB-TOPIC: Interpretation of quadratic function (solution sets from graph, equation of line of symmetry and minimum and maximum value or points from graph)

SPECIFIC OBJECTIVES: By the end of the lesson, the student will be able to:

- find the solution sets of a quadratic relation from graph
- identify the line of symmetry and write its equation
- find the minimum and maximum value or points from graph

RPK: Students can draw graph for a given relation.

REFERENCES: Concise Core Mathematics for Senior High Schools, Page 213-235

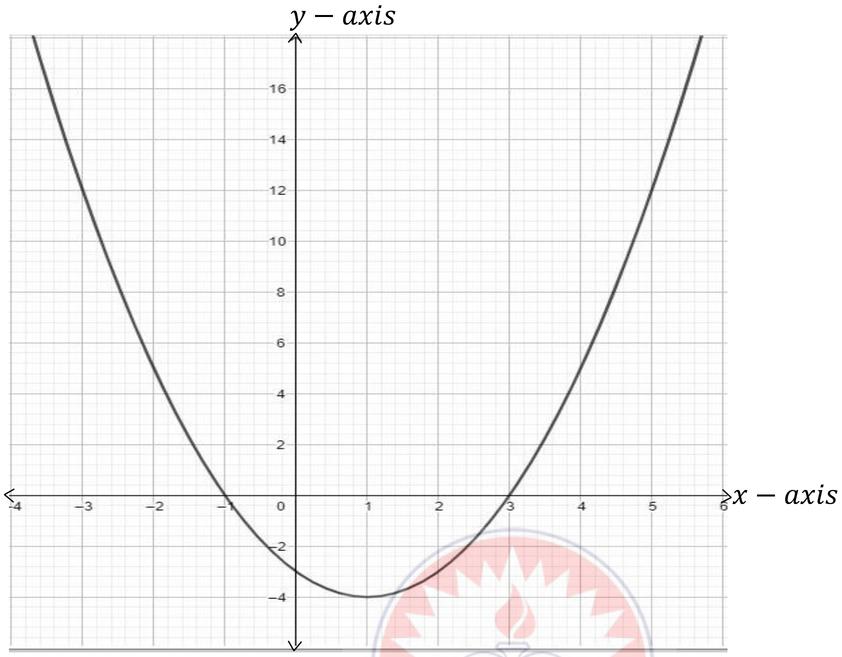
Ghana Senior Secondary School Mathematics Book 1, Page 260-270

Teaching Syllabus for Core Mathematics (2010), page 36-37

INTRODUCTION: Use question and answer method to revise students' RPK

QUESTION: Draw a graph for the relation $y = x^2 - 2x - 3$ in the interval $-4 \leq x \geq 6$.

EXPECTED ANSWER:



TEACHER AND LEARNER ACTIVITY

WHOLE CLASS DISCUSSION

Activity 1: Assist students to find the truth sets of a quadratic equation from a graph.

Activity 2: Assist students to establish that the quadratic graph is symmetrical about a vertical line and write its' equation as $x = k$. Where k is a real number?

Activity 3: Guide students to find the minimum and maximum value or points from graph and state the coordinate of the points where these value or points occur. Assist students to establish that the minimum and maximum value or points occur at the turning point of the graph.

Activity 4: Use varying examples to help students to find the minimum and maximum value or points from graph and state the coordinate of the points where these value or points occur.

CONCLUSION: Go through the lesson through questioning. end the lesson by giving students exercise, mark and correct mistakes.

Remind students to read on the next topic interpretation of quadratic function (Finding the range of value of x as y increases or decreases, range of value of x as $y > 0$ or $y < 0$. Finding the gradient of a curve).

CORE POINTS: finding solution sets of a quadratic relation from graph

-identifying the line of symmetry and writing its equation

-finding the minimum and maximum value or points from graph

REFERENCES: Concise Core Mathematics for Senior High Schools, Page 213-235

Ghana Senior Secondary School Mathematics Book 1, Page 260-270

Teaching Syllabus for Core Mathematics (2010), page 36-37

TEACHING LEARNING MATERIAL (TLM): Graph board, meter rule, marker, pencil, eraser graph books, Core Mathematics SHS Syllabus, SHS Core Mathematics Teachers' Guide, SHS Core Mathematics Text Book 2

EVALUATION: Use questions on the topic from students' work book to evaluate the lesson.

REMARKS: The lesson was successfully taught. About 65% grasp the concept.

LESSON: FOUR (4)

SUBJECT: Core Mathematics **YEAR:** 2 **DURATION:** 60 minutes

TOPIC: Solving Quadratic Equations by the Graphical Method

SUB-TOPICS: Interpretation of quadratic function (range of value of x as y increases or decreases, range of values of x as $y > 0$ or $y < 0$, gradient of a curve)

SPECIFIC OBJECTIVES: By the end of the lesson, the student will be able to:

-find the range of values of x as y increases or decreases,

-rang values of x as $y > 0$ or $y < 0$.

-find the gradient of the curve.

RPK: students can draw graph of a relation and find the solution set, the equation of the axis of line of symmetry and the minimum or maximum value or point from the graph.

REFERENCES: Concise Core Mathematics for Senior High Schools, Page 213-235

Ghana Senior Secondary School Mathematics Book 1, Page 260-270

Teaching Syllabus for Core Mathematics (2010), page 36-37

INTRODUCTION: Use question and answer method to revise students' RPK.

QUESTION: Draw table of values for the relation $y = x^2 - 2x - 8$ for the interval

$-2 \leq x \geq 4$. Choose a correct scale, plot the points in the Cartesian plane and draw the graph for the relation. Use the graph to find

I. the solution sets of $y = x^2 - 2x - 8$.

II. the equation of the axis of the line of symmetry.

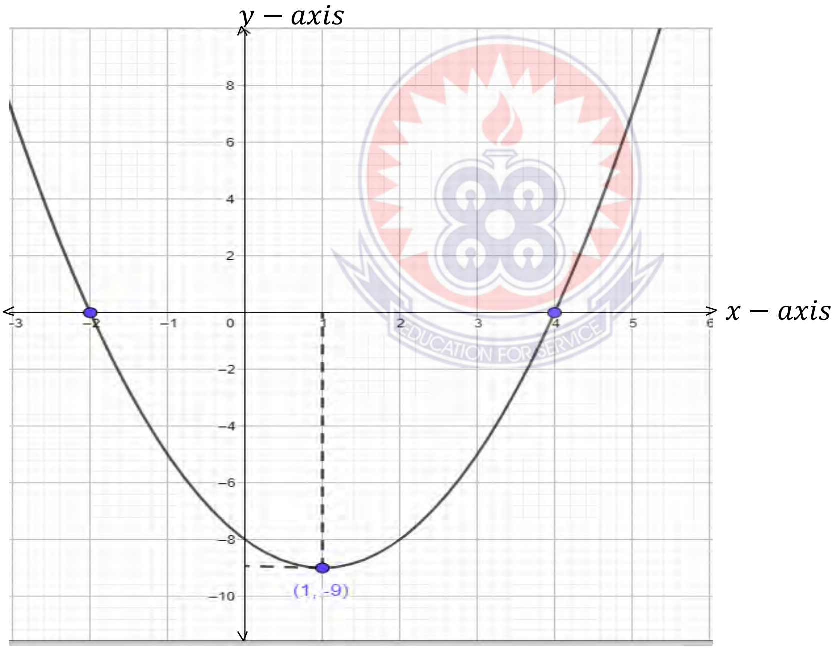
III. find the minimum value and point of the graph.

EXPECTED ANSWER:

Table of values:

x	-2	-1	0	1	2	3	4
x^2	4	1	0	1	4	9	16
$-2x$	4	2	0	-2	-4	-6	-8
-8	-8	-8	-8	-8	-8	-8	-8
y	0	-5	-8	-9	-8	-5	0

Graph of the relation $y = x^2 - 2x - 8$



I. the solution sets of $y = x^2 - 2x - 8$ is (-2,4)

II. the equation of the axis of the line of symmetry is $x = 1$

III. find the minimum value is $y = -9$ and minimum point of the graph is $(1, -9)$

TEACHER AND LEARNER ACTIVITY

WHOLE CLASS DISCUSSION

Activity 1: Assist students to find the range of values of x for which the graph is increasing or decreasing

Activity 2: Assist students to find the value of x for which $y \leq 0$ and $y > 0$.

Activity 3: Demonstrate to the students how to find the gradient of the curve.

Conclusion: Go through the lesson through questioning. End the lesson by giving students exercise, mark, and correct mistakes.

CORE POINTS: -finding the range of values of x as y increases or decreases, range of values of x as $y > 0$ or $y < 0$.

- finding the gradient of the curve.

REFERENCES: Concise Core Mathematics for Senior High Schools, Page 213-235

Ghana Senior Secondary School Mathematics Book 1, Page 260-270

Teaching Syllabus for Core Mathematics (2010), page 36-37

TEACHING LEARNING MATERIAL (TLM): Graph board, meter rule, marker, pencil, eraser graph books, Core Mathematics SHS Syllabus, SHS Core Mathematics Teachers' Guide, SHS Core Mathematics Text Book 2.

EVALUATION: Use questions on the topic from students' work book to evaluate the lesson.

REMARKS: The lesson was successful students participated very well.

APPENDIX D

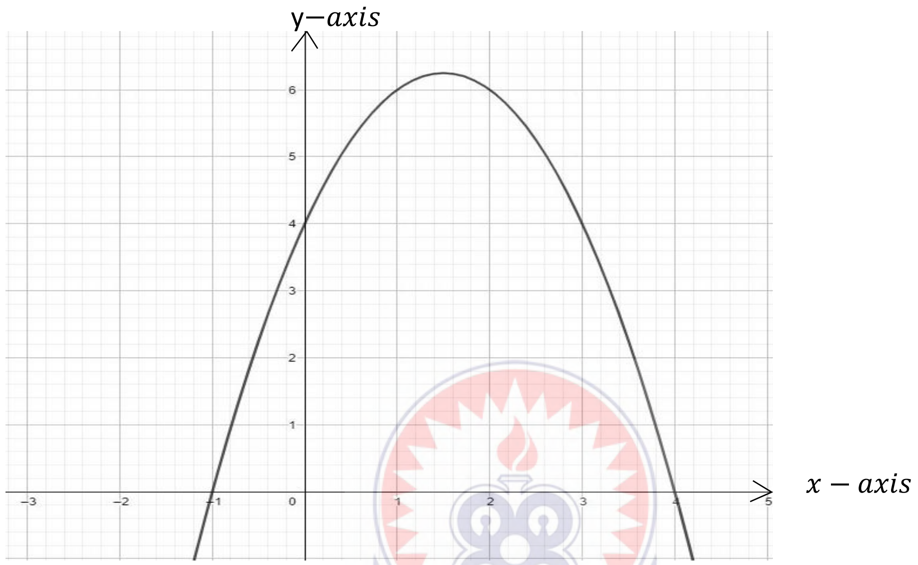
PRE-TEST

SECTION A

OBJECTIVES

ANSWER ALL QUESTIONS

The graph below shows the quadratic function $f(x) = -x^2 + 3x + 4$ for the interval $-3 \leq x \leq 5$ Use the graph to answer question 1 to 3



1. Find the truth set of $-x^2 + 3x + 4 = 0$
   a. $\{1, -4\}$ b. $\{1,4\}$
   c. $\{-1,4\}$ d. $\{-1, -4\}$
2. Find the maximum value of $f(x)$
   a. 1.5 b. 6.52
   c. 6.25 d. 6.0
3. What is the equation of the axis of symmetry?
   a. $y = -1.5$ c. $y = 1.5$
   b. $x = 1.5$ d. $x = -1.5$
4. Find the truth set of $x^2 - 3x = 10$
   a. $\{x: x = -2, x = 5\}$ b. $\{x: x = 0, x = 3\}$
   c. $\{x: x = 1.5, x = -2.3\}$ d. $\{x: x = 1, x = -2\}$
5. If $x^2 + 1 - (x - 2)(x + 1) = 0$, find the value of x .
   a. 3 c. -1
   b. 1 d. -3

6. Find the roots of the equation $x^2 = 3(2x + 9)$.

   a. $(3,9)$ c. $(3, -9)$

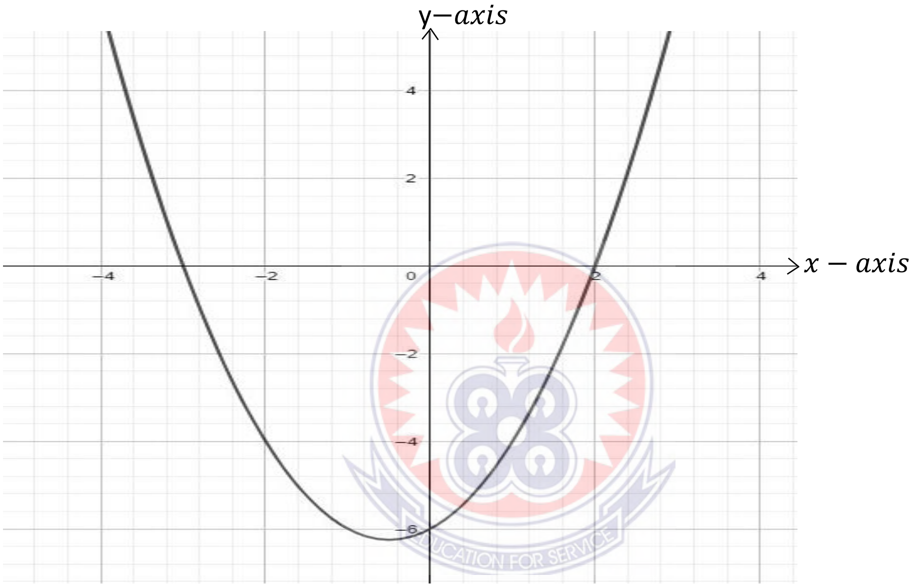
   b. $(-3, -9)$ d. $(-3,9)$

7. If one of the roots of the equation $x^2 - 5x + 6 = 0$ is 3, find the other roots.

   a. 1 b. 2

   c. 3 d. 4

The graph below shows the function $f(x) = x^2 + x - 6$ in the interval $-5 \leq x \leq 4$. Use it to answer question 8 to 10.



8. Find the range of values of x for which y decreases as x increases.

   a. $-4 \leq x < 3$ b. $-3 \leq x < 4$

   c. $-4 \leq x \leq -3$ d. $4 \leq x < 3$

9. The co-ordinate of the minimum point of $f(x) = x^2 + x - 6$.

   a. $(0.5, -6.2)$ b. $(-0.5, 6.2)$

   c. $(0.5, 6.2)$ d. $(-0.5, -6.2)$

10. For what value of x is $y < 0$

    a. $-3 \leq x < 2$ b. $3 < x < 2$

    c. $-3 < x \leq 2$ d. $-3 < x < 2$

SECTION B
ANSWER ALL QUESTIONS

1(a). Copy and complete the following table for the relation $f(x) = 2x^2 - 4x + 5$, for the interval $-2.5 \leq x \leq 5.5$.

x	-4	-3	-2	-1	0	1	2	3	4	5
y	53		21			3			21	

Using a scale of $2cm\ to\ 1unit$ on the $x - axis$ and $1cm\ to\ 5unit$ on the $y - axis$,

1(b). plot the points in the Cartesian plane

(i) draw the graph of the relation $f(x) = 2x^2 - 4x + 5$ for $-2.5 \leq x \leq 5.5$

Use your graph to find:

(ii). The equation of the line of symmetry.

(iii). The truth set of $2x^2 - 4x + 5 = 0$.

(iv). The co-ordinate of the minimum point of $y = 2x^2 - 4x + 5$.

(v). The range of values of x for which $y > 0$

2. (a) Copy and complete the following table for the relation $y = -x^2 + 2x + 3$ in the interval $-2 \leq x \leq 3.5$.

x	-2	-1	0	1	1.5	2	2.5	3	3.5
$-x^2$									-12.25
$2x$			0			4			7
3		3			3			3	
y	-5		3				1.75		-2.25

Using a scale of $2cmto\ 1unit$ on both $axis$,

2. (b) plot the points in the Cartesian plane

(i). draw the graph of the relation $y = -x^2 + 2x + 3$ for $-2 \leq x \leq 3.5$. Use your graph to find;

(ii). the solution set of the equation $-x^2 + 2x + 3 = 0$

(iii). the equation of the line of symmetry.

(iv). the minimum point of the graph.

(v). the minimum value of the graph

APPENDIX E

PRE-TEST MARKING SCHEME

SECTION A

1. c 2. c 3. b 4. a 5. d 6 d 7. b 8. a 9. d 10. D

(10 Marks)

SOLUTION FOR PRE-TEST SECTION B

1(a)

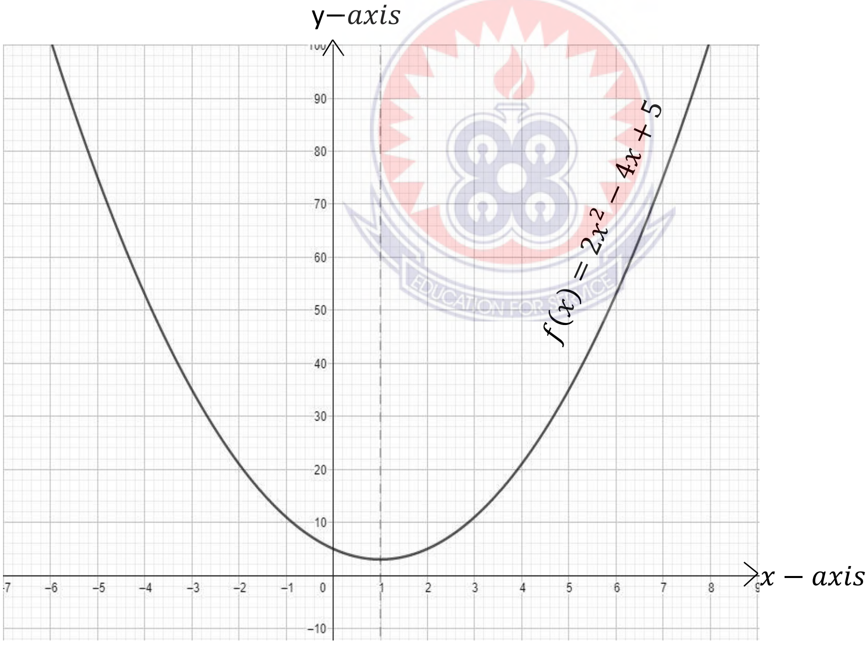
Table of values

x	-4	-3	-2	-1	0	1	2	3	4	5
y	53	35	21	11	5	3	5	11	21	35

$1\frac{1}{2}\ marks(-\frac{1}{4}ee)$

1(b) and 1b(i)

The graph of the relation $f(x) = 2x^2 - 4x + 5$, for the interval $-4 \leq x \leq 5$.



ANSWER: The relation has no real solution

(iv) The co-ordinate of the minimum point of $y = 2x^2 - 4x + 5$.

ANSWER: (1, 2.5)

(v) The range of values of x for which $y > 0$.

ANSWER: $x \leq 0$ or $x \geq 0$

(1) $mark$

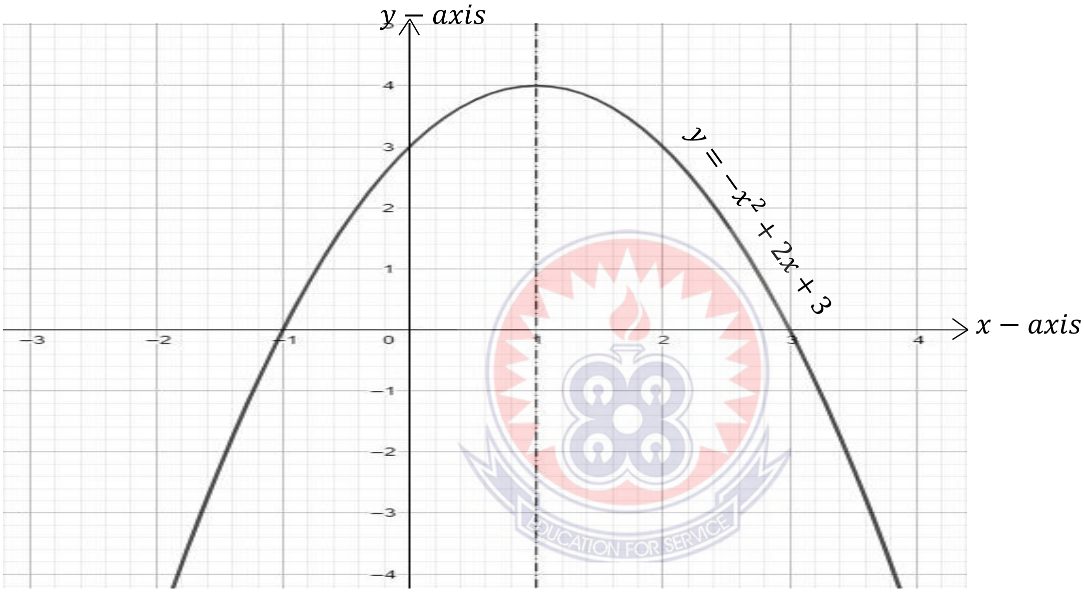
2. (a) Table of values

x	-2	-1	0	1	1.5	2	2.5	3	3.5
$-x^2$	-4	-1	0	-1	-2.25	-4	-6.25	-9	-12.25
$2x$	-4	-2	0	2	3	4	5	6	7
3	3	3	3	3	3	3	3	3	3
y	-5	0	3	4	3.75	3	1.75	0	-2.25

$1\frac{1}{2}\ marks(-\frac{1}{4}ee)$

2 (b) and 2b (i)

The graph of the relation $y = -x^2 + 2x + 3$ in the interval $-2 \leq x \leq 3.5$.



ANSWER: $x = 1$

(iv) the maximum point of the relation $y = -x^2 + 2x + 3$.

ANSWER: $(1, 4)$

(v) the maximum value of the graph

ANSWER: $y = 4$

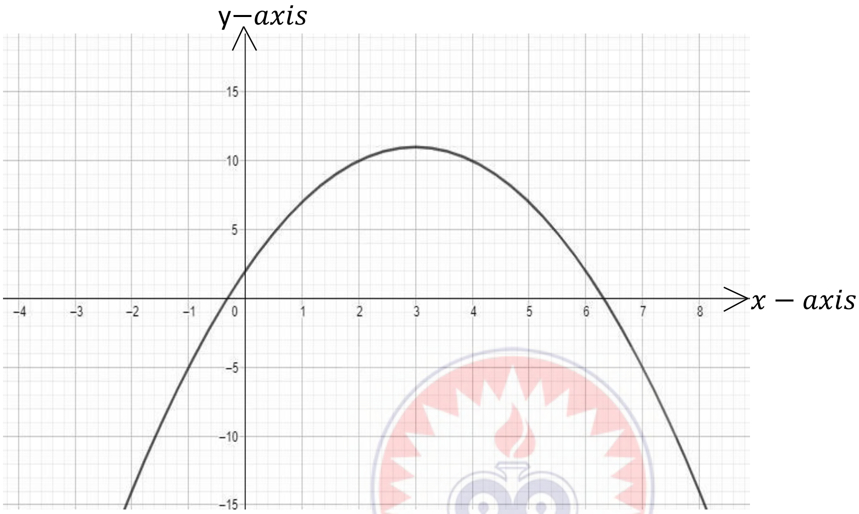
$(1)\ mark$

APPENDIX F

POST-TEST

SECTION A
OBJECTIVES
ANSWER ALL QUESTIONS

The diagram below shows the graph of $y = -x^2 + 6x + 2$. Use the graph to answer question **1** to 4



a. $x = 2$ b. $x = 3$

c. $y = 3$ d. $y = 11$

2. Find the co-ordinate of the maximum point of the curve $y = 2 + 6x - x^2$.

   a. $(11,2)$ b. $(6,11)$

   c. $(3,11)$ d. $(2,11)$

3. Find the truth set of the equation $2 + 6x - x^2 = 0$ correct to one decimal place.

   a. $\{0.317, 6.316\}$ b. $\{0.31, -6.31\}$

   c. $\{-0.31, 6.31\}$ d. $\{-0.3, 6.3\}$

4. What is the maximum value of the curve $y = 2 + 6x - x^2$.

   a. $x = -3$ b. $y = 11$

   c. $x = 3$ d. $y = -11$

5. Find the truth set of $x^2 - 3x = 10$.

   a. $\{x: x = -2, 5\}$ b. $\{x: x = 0, 3\}$

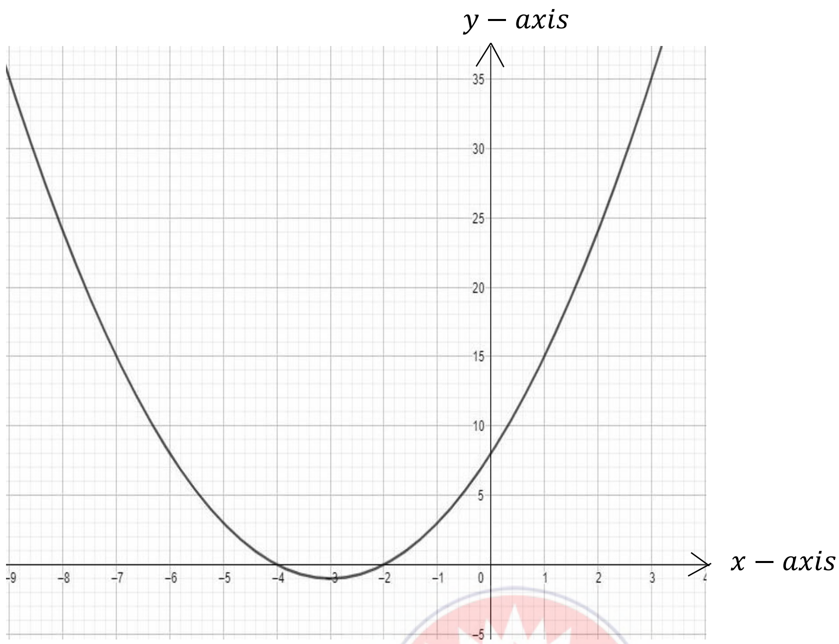
   c. $\{x: x = -1.5, -2.3\}$ d. $\{x: x = 1, -2\}$

6. Find the equation whose roots are $2\frac{1}{3}$ and $3\frac{1}{2}$

a. $6x^2 - 35x - 49 = 0$ b. $6x^2 - 35x + 49 = 0$

c. $-6x^2 + 35x - 49 = 0$ d. $6\,x^2 + 35x + 49 = 0$

The graph below shows a relation between x *and* y. Use it to answer question 7 to 10



8. What is the set of value of x for which $y = 0$.
   a. $\{-4,0\}$ b. $\{-4,-2\}$
   c. $\{0,-8\}$ d. $\{2,0\}$
9. Find the value of y when $x = -3$
   a. -1 b. 1.5
   c. 3.5 d. 1
10. Find the equation for the curve.
   a. $y = x^2 + 6x + 8$ b. $y = -x^2 - 6x + 8$
   c. $y = x^2 + 8x + 6$ d. $y = x^2 - 6x - 8$

SECTION B

ANSWER ALL QUESTIONS

1. (a) Copy and complete the following table for the relation $y = x^2 + x - 6$ in the interval

$-5 \leq x \leq 4$.

x	-5	-4	-3	-2	-1	0	1	2	3	4
y		6		-4			-4		6	

Using a scale of $2cm to\ 1unit$ on the $x - axis$ and $2cm to\ 2unit$ on the $y - axis$,

1(b). plot the points in the Cartesian plane

i. use the points to draw the graph of the relation $y = x^2 + x - 6$ for $-5 \leq x \leq 4$. Use your graph to find;

ii. the equation of the line of symmetry.

iii. the truth set of $y = x^2 + x - 6$.

iv. the co-ordinate of the minimum point of $y = x^2 + x - 6$.

v. the range of values of x for which $y > 0$.

2(a). Copy and complete the following table for the relation $y = -3x^2 + 4x + 7$ in the interval $-3 \leq x \leq 4$.

x	-3	-2	-1	0	0.5	1	1.5	2	2.5	3	3,5	4
$-3x^2$	-27					-3						-48
$4x$	-12	-8					6		10			16
7												7
y	-32			7	8.25			3		-8	-15.5	

Using a scale of $2cm to\ 1unit$ on the $x - axis$ $2cm\ to\ 5unit$ on the $y - axis$,

2(b). plot the points in the Cartesian plane

(i). draw the graph of the relation $y = -3x^2 + 4x + 7$ for the given interval. Use your graph to find:

(ii). the solution set of the equation $-3x^2 + 4x + 7 = 0$

(iii). the equation of the line of symmetry.

(iii). the maximum point of the relation $= -3x^2 + 4x + 7$.

(iv). the greatest value of the relation.

(v). find the values of x for which $-3x^2 + 4x + 7 = 0$

APPENDIX G

POST-TEST MARKING SCHEME

SECTION A

1. b 2. c 3. d 4. b 5. a 6. b 7. d 8. b 9. a 10. a

(10 MARKS)

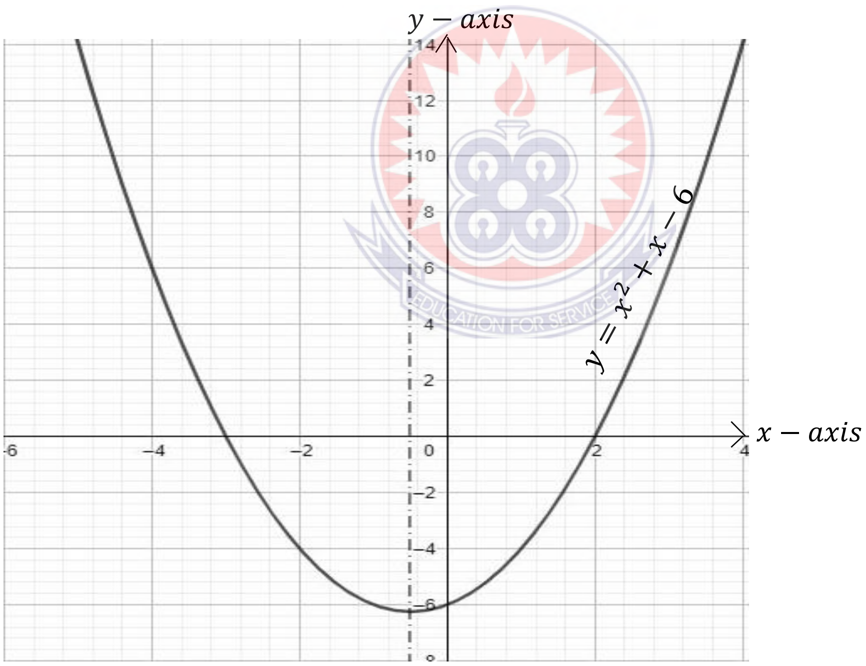
SECTION B

1. (a)

x	-5	-4	-3	-2	-1	0	1	2	3	4
y	14	6	0	-4	-6	-6	-4	0	6	14

$1\frac{1}{2}\ marks(-\frac{1}{4}ee)$

1.b and 1b (i)



(iii) The truth set of $y = x^2 + x - 6$

ANSWER: $\{x: x = -3, 2\}$

(iv) The co-ordinate of the minimum point of $y = x^2 + x - 6$.

ANSWER: $(-0.5, 6.2)$

ANSWER: $x < -3\ or\ x < 2$

$(1)\ mark$

2. (a)

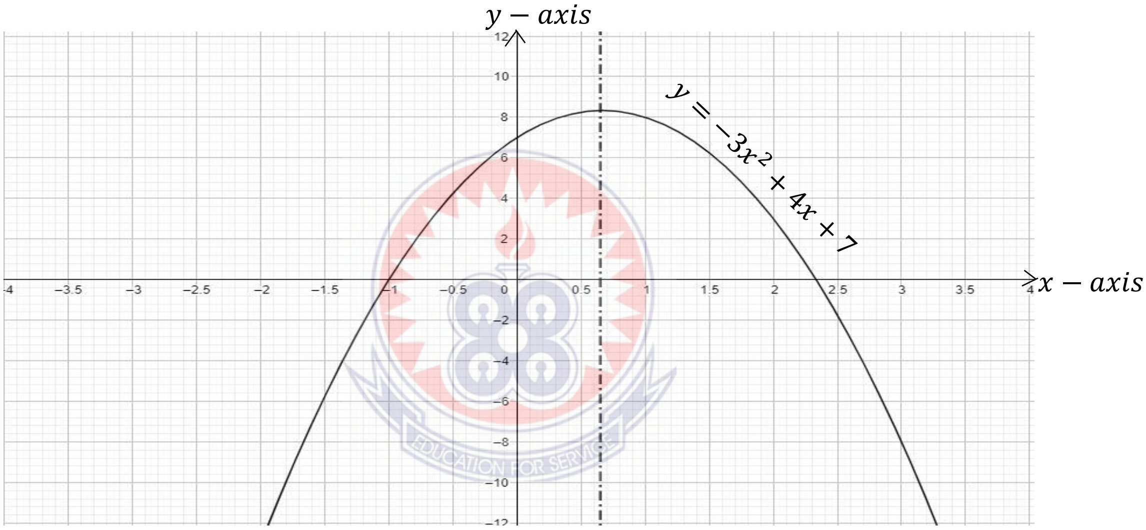
Table of values

x	-3	-2	-1	0	0.5	1	1.5	2	2.5	3	3.5	4
$-3x^2$	-27	-12	-3	0	-0.75	-3	-6.75	-12	-18.75	-27	-36.75	-48
$4x$	-12	-8	-4	0	2	4	6	8	10	12	14	16
7	7	7	7	7	7	7	7	7	7	7	7	7
y	-32	-13	0	7	8.25	8	6.25	3	-1.75	8	-15.75	-25

$1\frac{1}{2}\ marks(-\frac{1}{4}ee)$

2b and 2b(i)

The graph of the relation $y = -3x^2 + 4x + 7$ in the interval



i. the solution set of the equation $-3x^2 + 4x + 7 = 0$

ANSWER: $\{x: x = -1, 2.3\}$

ii. the equation of the line of symmetry.

ANSWER: $x = 0.5$

iii. the maximum point of the relation $y = -3x^2 + 4x + 7$.

ANSWER: $(0.5, 8.3)$

iv. the greatest value of the relation.

ANSWER: $y = 8.5$

v. the values of x for which $-3x^2 + 4x + 7 = 0$

ANSWER: $x = -1\ , x = 2.3$

APPENDIX F

UNSTRUCTURED INTERVIEW GUIDE

1. Were you taught quadratic equations at the Junior High School (JHS).
2. Did you understand the topic ‘quadratic equations’ at that level?
   If no, why?
3. Did your teacher motivate you when you provided the correct answers?
4. Were you given any assistance with questions that might have posed a challenge to you?
5. At what level at the Senior High School (SHS) were you first taught the topic ‘’solving quadratic equation by the graphical method’’?
6. Did you understand the topic at that level? If no, why?
7. To what extent did you understand the lesson, when the constructivist approach of teaching was used for the lesson by solving quadratic equation by the graphical method.
8. What is the difference between teaching with constructivist approach and teaching with the traditional (lecture) method?
9. Give one reason why you prefer the use of constructivist approach to the topic “solving quadratic equation by the graphical method”.
10. How did you perceive the use of constructivist approach to teach the topic solving quadratic equation by the graphical method?