UNIVERSITY OF EDUCATION, WINNEBA

THE EFFECTS OF PROBLEM-BASED LEARNING ON STUDENTS' COGNITIVE ACHIEVEMENTS IN SOME SELECTED TOPICS IN CHEMISTRY

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MARCH, 2022

DECLARATION

STUDENT'S DECLARATION

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

SIGNATURE: …………………………………..

DATE:…………………………………………...

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of 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: DR. ARKOFUL SAM

SIGNATURE: …………………………………..

DATE:…………………………………………...

DEDICATION

I dedicate this research to God Almighty who owns my life, to my Dad Elder Anthony Adjei for his tremendous support and encouragement towards my education. I also dedicate it to my lovely wife Mary Adjei.

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My sincere gratitude goes to the Almighty God for his tender mercies, guidance and protection through my entire life and education up to this level. I also express appreciation to my supervisor Dr. Arkoful Sam for his assistance, guidance and encouragement towards the successful completion of this research work. I would also like to extend my profound gratitude to the Staff of Nkrankwanta Senior High school for their immense support and advice. I am also grateful to all my friends for their support and prayers. Lastly I thank my family who always share with me my joy and sorrows. May the Almighty God bless them all.

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ABSTRACT

The purpose of the study was to determine the effects of problem-based learning on students‘ cognitive achievements in some selected topics in chemistry. The research design employed for the study was Quasi-Experimental specifically non-equivalent control group pretest–posttest design. The total population considered for the study consisted of Two hundred and fifty (250) second year senior high school students‘ who learn chemistry as an elective subject in Nkrankwanta Senior High Technical School. The sample size was Eighty-five (85) elective chemistry students in Nkrankwanta Senior High Technical School. Two intact classrooms were used for the study. The control group consisted of forty five (45) second year science students and the experimental group was equally Forty (40) second year Agricultural science students‘. Tests (Chemistry Achievement Test) and questionnaire with reliability coefficient of 0.80 were the instruments used for data gathering. Chemistry achievement pre-test was administered to both experimental and control groups. An intervention was carried out for the experimental group after which chemistry achievement post-test was also administered to both groups. Descriptive statistics such as percentages, mean , standard deviation and inferential statistics independent samples t-test, and paired samples t-test were used in analysing the collected data to answer four research questions and two null hypotheses, which were tested at 0.05 level of significance. The t-test results for control and experimental groups indicated that there was a statistically significance difference between students Post-test scores of both Control group exposed to Traditional method and Experimental group exposed to Problem-Based Learning approach. Also, the inferential statistics carried on the pre-test and posttest scores of students‘ in the experimental group exposed to Problem-Based Learning approach revealed there was no statistically significant difference between the cognitive achievement of male and female students‘ in chemistry. The study therefore recommends the need for inclusion of problem-based learning approach in the Senior High School chemistry syllabus and textbooks as this can result in significantly higher students‘ cognitive achievement in chemistry concepts such as redox reaction and acid-base concepts than the conventional approach (traditional learning approach).

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter presents the general background to the study, statement of the problem, purpose of the study, objectives of the study, research questions, and significance of the study, delimitations and limitations; and the organisation of the study

1.1 Background to the Study

Chemistry is the study of the nature and properties of all forms of matter as well as substance that make up our environment and the various changes which these substances undergo in different conditions. Chemistry is a branch of physical science which links physical and biological science together. Chemistry has long been a traditional part of academic curriculum in schools and it is usually studied alongside other related subjects such as biology, physics and mathematics. It is a core subject in the study of many biological science courses such as Medicine, Biochemistry, Microbiology, Pharmacy, and Engineering among others. Thus a sound knowledge of chemistry is of great importance to many pupils and the community at large. Akpan (1994) stated that all form of human endeavors and absolutely nothing goes on in science without the application of chemistry. The importance and role of science education (especially chemistry) cannot be over emphasized. Chemistry is considered as central in the drive of global sustainable economic development. The knowledge acquired in chemistry plays major roles which presently allow man to experience an era in scientific and technological development that affects his life in one way or the other such as in food (fertilizers and insecticides), clothing (textile, fibers), housing (cement, concrete, steel), Medicine (drugs), Transportation (fuel, alloy materials). According to Emendu (2014), with these indispensable knowledge richly acquired, man can shape and reshape his world for his benefit. Hence, the development of the nation is usually measured by the degree and extent of growth brought to it through the enterprise of science education and a gate way to it is chemistry education. Festus and Ekpete (2012) stated that any nation aspiring to be scientifically and technologically developed must have adequate level of chemistry education. Students' performance in chemistry depends on many factors and stands out to show how well students are doing. Therefore, teaching methods becomes an important path-way that should not be under mind by chemistry teachers and should be applied appropriately in order to enhance learning outcomes of students. In recent decades, there has been a shift in science education towards more student-centered teaching approaches.

Dewey (1923) believed the world was constantly changing and students needed to be active learners engaged in the learning process. In his opinion, traditional education created the wrong kind of experience to promote learning. According Barron and Darling-Hammond (2008), students learn at deeper levels and perform better on complex tasks by engaging in authentic projects that draws subject knowledge to solve real-world problems. Indeed, relevant literature has shown that when students are involved in the learning process actively; meaningful learning, understanding and retention can be enhanced (Ausubel, 1963). According to DeBacker and Nelson (2000), classroom environments which focus on students' effort and strategy use instead of their ability, encourage students to compare and realize the difference between their past and present performance, and reduce the emphasis on grade and social comparisons can improve student learning. Moreover, Torp and Sage (2002) points out that, ―students need to understand at deeper levels, and to understand at deeper levels they need to engage in sustained thinking about topics or issues-to crawl inside ideas and expose misconceptions while making multiple connections" (p.31).

In fact, one of the primary goals of research in education is to help students apply scientific concepts to real life problems (Chin & Chia, 2006). According Ausubel, Novak, and Hanesian (1968), to such meaningful learning is encouraged whenever students relate new knowledge to relevant concepts they already know. For meaningful learning to take place, however, students should not acquire isolated facts; they should construct new knowledge by drawing relationships among several different concepts, both new and old. Therefore, it should be noted that regardless of which instructional approach is employed in the classrooms, students' prior knowledge has great influence on their further learning. Meaningful learning is also associated with a meaningful learning approach (Etwistle & Ramsden, 1983), which refers to an intention to understand the material. Entwistle and Ramsden (1983), reported that students who adopt a meaningful learning approach are likely to find the task more interesting and easier to understand. In general, a meaningful approach is found to be associated with a deep level of understanding.

In contrast, the rote approach to learning of science involves both rote memorisation and the syllabus boundness. In this approach, the student's intention is to meet the minimum course requirements and their external motive is to avoid failure by simple recall (Araz, 2007). Rote approach to learning is not sufficient to achieve a sound understanding of scientific concepts (Cavallo, Potter, & Rozman, 2004). It is widely acknowledged that chemistry is one of the most difficult subjects in secondary science as it contains aspects of chemical reactions that need to be understood in order to solve chemistry related problems (Abdullah, Hasan, & Osman, 2013). Students' interest towards chemistry continues to dwindle not because schools lack professional chemistry teachers alone, the teaching approaches or methods used by teachers in teaching chemistry is also one factor to be considered. Several factors have been identified as the objectives of science instruction but the commonest factor documented by researchers is inappropriate and uninspiring teaching methods adopted in the teaching and learning of Science (chemistry).

Conventional method of teaching refers to teaching using chalk and board for teachers, pen and paper for students (Nnorom, 2008). Teacher centered method does not promote skill acquisition, objectivity and critical thinking ability among learners. There is the need for more activity oriented, students centered and innovative method that can develop in the students' science process skills, which include problem-based learning method. Problem based-learning approach is a student centered method where the teacher and students play equal active role in teaching and learning process. The teachers' primary role is to coach and facilitates student learning and overall comprehension of material while the students construct new ideals and concept based on their past knowledge. In order to solve chemistry problems in an acceptable manner, the problem solver must have both conceptual scientific and procedural knowledge (Festus & Ekpete, 2012).

Various methods of teaching chemistry are known, such include guided discovery problem-solving, discussion, expository individualistic methods. These methods depend on various forms of teacher–student-activities through some methods are more activity oriented than others. (Nakhleh, 1993), opined that, chemical educators and teachers have often assumed that success in solving chemistry problems should indicate mastery of the chemistry concepts, which is not so. Problem-Based Learning (PBL) is an alternative approach to teaching which is not prescriptive in nature. Problem-based learning covers a broad family of schemes that include problem solving, project-based teaching, inquiry, case-based instruction and grounded instruction. Students' active involvement in trying to solve some problems or answer some questions is central to all the different strategies listed. The best way for students to learn science is to experience challenging problems and the thoughts and actions associated with solving them (Greenwald, 2000). Problem-solving is a systematic approach that reviews learning competencies, comprehending and composing critical and creative thinking. Problem based learning enables students to become active participants in solving problems and answering questions.

In the problem based-learning approach, students are confronted with problems that require critical thinking and analysis of ill structured problems through development of hypotheses and analysis of data linking the new knowledge into their thinking and decision making. It is one of the innovative teaching strategies that can help students understand difficult concepts. Problem- based learning is a student-centered teaching approach that enables students to become active participants in solving problems, answering questions and doing more to explore knowledge. It helps students to become familiar with a scientific reasoning process that facilitates critical thinking as it provides answers to fill gaps in students' knowledge. Problem based learning approach encourages students to think about the way they do things. Through problem solving approach, students reviews their learning competencies, comprehending and composing critical and creative thinking. These features are most important dimensions of thinking and learning in regardless of the acknowledgement of the importance of developing problem-solving skills.

According to Hiebert and Stigler (2004), one factor that is found in international studies which characterises higher performing countries is the use of cognitively demanding tasks and having students engage in critical thinking and reasoning. PBL, as a form of instructional, is an instructional method in which students learn through facilitated problem solving (Hmelo-Silver, 2004). Studies have shown that PBL has great impact to higher education students in various disciplines (Chapman, 2002; Kim and Kwon, 2003; Goodnough, 2008). Students play active roles in the class, thus enhancing their skills such as problem solving skills, leadership and decision making skills (Hmelo- Silver, 2004). PBL pedagogy, promotes learning through the concept of ‗learning by doing', which creates an opportunity for students to learn by experiencing the process of problem solving (Wood-Robinson, Lewis, & Leach, 2000). PBL has spread to diverse disciplines, from schools to higher education levels, including science education (Wong & Day, 2009).

Problem based solving technique is a type of learning which involve problems that give students opportunity to design an investigative activity using problem-solving to arrive at conclusion (Booth & Thomas, 1999). It involves an experimental learning process that composed of data collection, experiment, observation, explanation and drawing conclusions (Bell, 2010). The use of problem based learning approach in teaching helps to stimulate students' understanding on how to find information that are linked to problem, and this increase their thinking ability. Various researchers have reported successful implementation of problem based learning in the classroom, and students problem solving skills and thinking ability were improved (Aidoo, Boateng, Kissi, & Ofori, 2016). In the quest to pursue deeper learning for students, PBL has emerged as a comprehensive approach to classroom teaching and learning that is designed to engage students in investigation of authentic problems (Blumenfeld et al, 1991; McGrath, 2004; & MaKinster et al, 2001). It is against this background that this research sought to examine the problem-based learning method of teaching some selected topics and its effect on students' cognitive achievements in chemistry.

1.2 Problem Statement

The persistent low performance and lack of interest of students in chemistry has been a major concern of chemistry educators and researchers. Several factors have been said by these researchers to be responsible for the trend of dwindling attitude and interest towards chemistry by students among which is the instructional approach used by chemistry teachers in teaching chemistry, such as the conventional method of teaching, inadequate science process skills, gender stereotype and lack of confidence by students in tackling chemistry problems, the abstract nature of chemistry, the mathematical nature of chemistry and the competitive nature of the subject. Although there is a vast amount of research and literature available on problem-based learning (Barrows, 1986; Camp, 1996; Dombrowski, 2002; Evensen & Hmelo, 2000; Greening, 1998; Finucane, Johnson & Prideaux, 1998; Major & Palmer, 2001) but few studies have delved into the effects of PBL in teaching some selected topics in chemistry.

In Ghana, teaching sciences in S.H.S generally appears to be through lecturer notes-giving and talking, chalkboard illustrations, demonstrations and other teacher centered methods which enable students to only form mental models of concepts presented to them. This method of presentation of concepts may lead to loss of interest in learning, as students tend to forget easily what they learn. Also, since it is the same monotonous of only teachers doing the talking and learning, the enthusiasm to learn is absent. Science subjects, especially chemistry, tend to be the most affected since most of the concepts presented are abstract and also requires the student to put in a lot of effort in forming mental models to aid understanding. Through the researcher‘s experience and encounter with many students learning Chemistry at Nkrankwanta Senior High Technical School, points out that students pursuing a course in chemistry attitudes and interest continue to dwindle and many students even have a misconception that, chemistry is a difficult subject to learn and therefore few students have the interest of pursing further to study chemistry at the tertiary level. Most learners have a negative attitude towards chemistry, hence low attitude towards problem – solving in Chemistry. They lack interest in the subject and do not grasp the concepts of chemistry. Therefore, there is the need to find the basis for enhancing positive attitude of learners.

Therefore improving performance of learners and enhancing positive attitude requires the use of a more engaging approach and one among them is the problem-based learning approach. Throughout the researcher‘s years of teaching and examining students at Nkrankwanta Senior High Technical School, he realised that most students pursuing a course in General Science and Agricultural Science who learn chemistry as a subject do not have better understanding of some chemistry concepts they are been taught but rather had to resort to rote-learning for only examination and not for life as it supposed to be.

The researcher further discovered that most of the learners at Nkrankwanta Senior High Technical School do not have interest in chemistry and they do not spend time in learning as they do for other subjects with their thinking that, chemistry is very difficult to learn without the guidance of the chemistry teacher, these students have always been failing to solve calculations and equations problem in chemistry correctly after learning and exercising many other similar problems. Several approaches have been adopted over the years to improve learners‘ low achievement in chemistry by the school‘s administration. Some of these approaches include organising workshops for chemistry teachers in the school, attending Regional Science workshops and increasing contact hours for chemistry lessons on the teaching timetables, yet the low performance of learners still persist. This persistence in low performance of learners may mean that the real source and solution to the problem has not been systematically established. This study contends that a possible solution to the problem may lie in the teaching of chemistry using an appropriate teaching approach, which is the essence of this study.

1.3 Purpose of the Study

The purpose of the study was to ascertain the effect of problem-based learning on Senior High School students‘ cognitive achievements in some selected topics in chemistry.

1.4 Objectives of the Study

The objectives of the study were to:

1. Investigate the extent to which the use of Problem-based learning will enhance students‘ achievement in chemistry.
2. Ascertain the differential impact of the problem-based learning approach on male and female students‘ cognitive achievement in the selected topics in chemistry**?**
3. Evaluate students‘ attitude towards the use of problem-based learning technique as a learning strategy in chemistry.
4. Identify the conceptual difficulties senior high school students encounter in solving chemistry problems.

1.5 Research Questions

1. What will be the extent of student‘s achievement in chemistry when exposed to Problem based learning approach?

2. What is the differential impact of the problem-based learning approach on male and female students‘ cognitive achievement in the selected topics in chemistry**?**
3. What is the attitude of students towards the use of Problem-based learning technique as a learning strategy in chemistry?
4. What conceptual difficulties do senior high school Students have in solving chemistry problems?

1.6 Null Hypothesis

The following null hypotheses were tested:

H01: There is no statistically significant difference between mean chemistry achievement pretest and posttest scores of students in experimental group.

H02: There is no statistically significant difference between the mean chemistry achievement pretest and posttest scores of male and female students in the experimental group.

1.7 Significance of the Study

This research will help Senior high School students and Chemistry teachers at large to know the effect of problem based learning approach compared with the traditional methods of teaching chemistry, which will go a long way to improve the performance of students‘ in chemistry. This research will also help students develop positive attitude towards the study of chemistry in most Senior high Schools in the country, which will go a long way to help chemistry educators know the reason why most students dislike some topics in chemistry and the best method to be used in teaching these topics to the understanding of the learners. It would also provide an insight into the effect of PBL on SHS students‘ attitudes and motivation towards learning of chemistry. Findings of the study would contribute to the body of knowledge as it provides evidence needed to justify whether to adopt PBL strategy in Ghanaian SHS, or continue with the widely used traditional learning instructional strategy in teaching (chemistry) science concepts. It would also serve as basis reference document for further research work.

1.8 Delimitations of the Study

The research was narrowed to only one Senior high school in the Bono Region. It was also delimited to only form two students. The study was additionally delimited to an aspect of chemistry, focusing on redox reactions, acid and bases as topics in the SHS elective chemistry syllabus.

1.9 Limitation of the Study

Although this research was carefully prepared, there were some unavoidable limitations. The first limitation was the sample size. Generally, sample size should be large in order to make a valid general conclusion. However, the sample size in this study was only restricted to only eighty five (85) SHS form 2 students. Therefore, the sample size was too small in order to make a general conclusion on the study. Also large number of SHS across the nation should have been targeted in this study. However this study targeted only Nkrankwanta Senior High Technical School in the Bono Region of Ghana due to lack of funds, proximity and accessibility. This was done in order to cut down cost and for effective management of time to complete the study within the time limit and also enable the researcher to undertake a thorough and adequate data collection. Therefore the use of the outcome of this study should be with circumspection.

1.10 Organisation of the Study

The study outlined the effect of problem-based learning on Senior High School cognitive achievement in some selected topics in Chemistry. The study was organized into five chapters. Chapter one presents background knowledge of the problem. It also displays purpose of study, objectives, and significance of the study. Chapter Two presents a review of related literature relevant to the study theoretical and conceptual frameworks. Chapter Three highlights the methods that will be appropriate for the study. These methods include the research design, study variables, location of study, target population, sampling techniques, construction of research instruments, validity and reliability of data, and data collection techniques. Chapter Four discusses methods of data analysis used in the study. The results are explained and discussions of research findings are presented in Chapter Four. Chapter Five contains a summary of the study, conclusion, and recommendation. Implication of findings and suggestion for additional research are outlined in Chapter Five.

CHAPTER TWO

LITERATURE REVIEW

2.0. Overview

This chapter discusses the literature relevant to the study, followed by some theories of learning. This chapter considered some discussions on recent related studies on problem based learning approach in relation to the topic of this study. It also had review of literature on various form of approach to the teaching and learning of Senior High School chemistry. The areas covered in the literature review were: Theoretical framework underpinning the Study, Theories of Learning**.** Behaviorist Learning, Cognitive/Constructivist Learning, Humanist Learning**,** Constructs and Attributes of Radical and Social Constructivism Classroom, Radical Constructivist Theory, Social Constructivist Theory, The Concept of Problem-Based Learning, Goals of Problem Based Learning, Characteristics of Problem Based Learning, Implementing Problem-Based Learning in the Senior High School Chemistry Education, The Relevance of PBL in the Science Classroom, Teaching and Learning Methods used in teaching of Chemistry, Inquiry-based learning, Teacher-Centred Method of Teaching Science, Student-Centred Approach of Teaching Science, The Relevance of Teaching Method in Science Education, Empirical Studies On PBL in Chemistry, Problem -Based Learning and Science Achievement

2.1 Theoretical Framework Underpinning the Study

This study drew its theoretical framework from constructivism which has two belief systems: radical constructivism and social constructivism. Formalization of the theory of radical constructivism, according to Von Glasersfeld (1990) is generally attributed to Jean Piaget (1896-1980). Von Glaser field (1990) also added that, Piaget suggested that through processes of accommodation and assimilation, individuals construct new knowledge from their experiences. Radical constructivists view learning as a process in which the learner actively constructs or builds new ideas or concepts based upon current and past knowledge experience. In terms of psychology, recognition to the further development of radical constructivism in regard to classrooms and learners can be given to Dewey (1859-1952), Jean Piaget (1896-1980), and Lev Vygotsky (1896-1934). Social constructivism is considered as an extension of the traditional focus on individual learning to addressing collaborative and social dimensions of learning. Social constructivists posit that knowledge is constructed when individuals engage socially in talk and activity about shared problems or tasks (Jones, 1996), and that knowledge is interwoven with culture and society (Ernest, 1999).

What these theories are suggesting is that a learner‘s mind is not like an empty vessel that has to be filled with knowledge but that a learner is an active learner (as opposed to a passive learner) who is capable of constructing the meaning of new knowledge from known and related experiences and also through social interaction with other learners in a group. The implication of these to teaching is that teaching should be learner centered rather than teacher centered, and in a collaborative and cooperative small-group and large-group discussion environment. According to Vygotsky (1980) learners are capable of performing at higher intellectual levels when asked to work in collaborative situations than when asked to work individually. The radical constructivist and social constructivist theories of learning provide the theoretical framework upon which this study is based.

2.2 Theories of Learning

2.2.1 Behaviorist learning

The behaviorist view of learning was introduced by theorists such as Thorndike, Pavlov, Watson, Guthrie, and Hull. Behaviourism is a worldview that operates on the principle of stimulus-response‗. All behaviour has its origins in external stimuli, and all behaviour can be explained without the need to consider internal mental states or consciousness. From this view of the learning process, educators and teachers aim to change human behaviour. The locus of the learning is to condition students to respond to stimuli from the external environment, so that learners learn to adapt to any environment. The main purpose in this view is to produce learners that can change their behaviour in desirable ways. The educator must then manipulate the surrounding environment to elicit the desired response. The learner, it is argued, will develop skills as a result of such training and gain in competence, based on their education. Examples of educational practice based on a behaviourist approach to learning are things such as rote-learning; direct instruction (e.g., lectures); prescriptive feedback; competency-based education; and design of learning outcomes.

2.2.2 Cognitive/constructivist learning

A cognitivist approach to learning essentially argues that the black box of the mind should be opened and understood, with the learner viewed as an information processor (like a computer). Koffka, Kohler, Lewin, Piaget, Ausubel, and Gagne are the main proponents of this approach to learning. Constructivism assumes that learning is an active process of mental construction in the learners ‗mind, and that the learner is an independent information constructor or creator. In the constructivism environment, the learners actively construct or create their own subjective representations of objective reality.

New information acquired is linked to prior knowledge, thus mental representations are subjective and personal. In a cognitive/constructivist approach to learning, the learning process is viewed as an internal mental process involving insight, information processing, memory, perception. The locus of learning is internal cognitive structuring, which is concentrated only on thinking. To develop capacity and skills to learn better in the future is the main objective for this approach. The educator has to structure content and the curriculum for each learning activity. The manifestation of learning is to build cognitive development such as intelligence; learning and memory as function of age, and ultimately for the learner to learn how to learn. Key terms or ideas used to describe learning in this approach are schemata; information processing; symbol manipulation; information mapping; and mental models. Educational practices in this approach include problem-based learning; inquiry-based learning; cooperative learning; collaborative learning; active participatory learning; activity and dialogical process; anchored instruction; cognitive apprenticeship (scaffolding); and inquiry and discovery learning.

2.2.3 Humanist learning

Humanist learning is a learning process seen as a personal act employed to fulfill a learners _potential. Humanism is a paradigm, philosophy, and pedagogical method that believes learning is best viewed as a personal and particular act, to fulfill one_s potential. The main objective, according to humanists, is to help the learner to become self-actualised, autonomous and independent in everything they have learned. The teacher facilitates learner improvement and development as a whole person.

2.2.4 Constructs and attributes of radical and social constructivism classroom

There is great deal of overlap between a radical constructivist and social constructivist classroom. The exception of the latter is that greater emphasis is placed on learning through social interaction, and the value placed on cultural background. Radical constructivist learning is based on active participation of learners in problem-solving and critical thinking. Students use inquiry methods to ask questions, investigate a topic, and use variety of resources to find solutions and answers. They make conjectures, explain their reasoning, validate their assertions, and discuss questions from their own thinking and that of others. The role of the teacher in a radical constructivist classroom is to probe students thinking, provide problems that can be solved in different ways, provide problems which have the capacity to engage all students in class, and devise situations that will challenge learners way of thinking.

A teacher in this classroom acts as ―a guide on side” (facilitator) by providing students with opportunities to test the adequacy of their current understanding. In social constructivist classrooms learning is student-centered and project based. Collaborative learning is the main process of peer interaction that is mediated and structured by the teacher. Students learn by: developing shared meanings through group participation, participating in system of practices that foster group dynamics, socially sharing cognitions that promote group or community participation, and social interaction that constructs contexts, knowledge, and meanings. The role of the teacher in a social constructivist classroom is to set up a system that promotes social interaction that constructs and reconstructs shared knowledge and meaning and probe learners to go over the limit of their understanding. The role of students in a radical constructivist learning environment is that they play more active roles in and accept more responsibilities for their own learning, whereas in a social constructivist learning, students are expected to cooperate and contribute to discussions with other peers in social groups. (Derry, 1996).

2.2.5 Radical constructivist theory

Radical constructivism is a theory of knowledge (epistemology) that argues that humans generate knowledge and meaning from interaction between their experiences and their ideas. The basic idea in this theory is that learning is an active and constructive process with the learner viewed as an information constructor. In the constructivist classroom the teacher becomes a guide for the learner, providing bridging or scaffolding, helping to extend the learner‘s zone of proximal development. The student is encouraged to develop meta-cognitive skills such as reflective thinking and problem solving techniques. Independent learners are intrinsically motivated to generate, discover, build and enlarge their own frameworks of knowledge. Researchers such as Fosnot (2013), suggested that a constructivist approach to learning builds on the natural innate capabilities of the learner. From this perspective, the learner is viewed as an active, not passive person, actively constructing understanding through the use of authentic resources and social interaction (Kauchak & Eggen, 1993).

According to Brown (2006), central to the notion of constructivism is the view that experience and knowledge are filtered through the learner‘s perceptions and personal theories. The focus of constructivism is on cognitive development and deep understanding in which learning is nonlinear and learners are encouraged to freely and actively search for solutions (ingredients of a problem-solving approach). Such an active learning coupled with deeper construction of meaning of knowledge is likely to promote retention, comprehension and high-level critical thinking skills which are attributes needed by the learners to improve their performance in science. It is the desire of the researcher that science teachers in Nkrankwanta Senior High Technical School should create a meaningful learning experience for science students by creating an environment which supports investigation and problem solving through constructivist learning. It is rightly argued by Brooks and Brooks (1999),that: Learners control their learning. This simple truth lies at the heart of the constructivist approach to education. Learners must be permitted the freedom to think, to question, to reflect, and to interact with ideas, objects, and others – in other words, to construct meaning. (Auger & Rich, 2006).

This radical constructivist learning that promotes deeper construction of meaning of knowledge is lacking in the science students in Nkrankwanta Senior High Technical School during teaching and learning of chemistry. The conventional approach to teaching used by most Ghanaian chemistry teachers does not offer students the opportunity to learn chemistry actively and thereby construct their own meaning of knowledge through thinking to solve chemistry problems. This learning gap explains the recurring low performance in chemistry by the students at Nkrankwanta Senior High Technical School and therefore this study examined how this learning gap might be filled through the use of a problem-based learning approach in teaching chemistry. Recommending constructivist paradigm in teaching and learning chemistry, Fletcher (2005) argues that ―constructivist learning paradigm should be considered as an alternative to transmission view since a fundamental goal of chemistry instruction is to help learners build structures that are more complex, powerful and abstract than those learners possess before instruction. This radical constructivist learning paradigm suggests that students learn best when learning is: active, self-directed, based on problems related to their experiences and perceived as relevant to their needs, and intrinsically motivated. Such learning is at the roots of constructivism and can take place in a social working environment that promotes sharing of knowledge and experiences gained. This manner of learning is best experienced through a problem solving approach of learning chemistry in social groups.

2.2.6 Social constructivist theory

Social constructivism emphasizes that all cognitive functions including learning are dependent on interactions with others (e.g. teachers, peers, and parents). Therefore learning is critically dependent on the qualities of a collaborative process within an educational community, which is situation specific and context bound (Eggen and Kauchak, 1999; McInerney & McInerney, 2013; Schunk, 2012). However learning must also be seen as more than the assimilation of new knowledge by the individual, but also as the process by which learners are integrated into a knowledge community.

In the social constructivism nothing is learnt from scratch; instead it is related to existing knowledge with new information being integrated into and expanding the existing network of understanding. The successful learner is therefore one who embeds new ideas within old and for whom understanding expands to encompass the new experience. Therefore, a social constructivist learner's view of the world will always be subjective, as each individual will interpret experience via a different pre-existing framework of understanding and will develop their own unique view of the world. Social constructivism maintains that learning is based on real life adaptive problem solving which takes place in a social manner through shared experience and discussion with others such that new ideas are matched against existing knowledge and the learner adapts rules to make sense of the world. Social constructivism places the focus on the learner as part of a social group, and learning as something that emerges from group interaction processes, not as something which takes place within the individual. Learning is seen as an active socially engaged process, not one of a passive development in response to external forces (McMahon, 1997; Derry, 1999).

To the social constructivist, to learn is to see the meaning or significance in a social experience or concept. Therefore social constructivism acknowledges the uniqueness and complexity of the individual learner and values, utilizes and rewards it as an integral part of the learning process (Wertsch, 1997).

Social constructivism focuses on an individual's learning that takes place as a result of discussions and interactions in the group and among groups. Many studies argue that discussion plays a vital role in increasing students" ability to test their ideas, synthesize the ideas of others, and build deeper understanding of what they are learning (Corden, 2001; Nystrand, 2006; Reznitskaya, Anderson & Kuo, 2002; Weber, Maher, Powell & Lee, 2008). Large and small group discussion also affords learners opportunities to exercise self-regulation, self-determination, and a desire to persevere with tasks (Corden, 2001; Matsumara, Slater & Crosson, 2008). Additionally, discussion increases student motivation, collaborative skills, and the ability to problem solving (Dyson, 2000; Matsumara, Slater & Crosson, 2008; Nystrand, 1996). Increasing learners" opportunities to talk with one another and discuss their ideas increase their ability to support their thinking, develop reasoning skills, and to argue their opinions persuasively and respectfully (Reznitskaya, Anderson & Kuo, 2007).

Furthermore, the feeling of community and collaboration in classrooms increases through offering more chances for learners to talk together (Barab, Dodge, Thomas, Jackson, & Tuzun, 2007; Hale & City, 2002; Weber, Maher, Powell & Lee, 2008). Knowledge, as seen by Jaworski (2007), is socially rooted, with individuals forming identity as part of social engagement. (Engagement here denotes active participation and mental inclusion). These authors suggest that research should focus on the potential for small-group work in order to develop learner‗s critical thinking and problem solving skills. This study intends to examine the effects social group learning (cooperative problem solving) will have on learner‘s achievement (performance) in chemistry when they are engaged in learning through methods that are characteristics of a problem-based learning approach.

2.3 The Concept of Problem-Based Learning

In today‘s world, one of the main goals of science education is to help students develop scientific thinking. In order to accomplish this, there is need for creating rich learning environments in which students are involved in inquiry based tasks requiring cognitive processes used by scientists while conducting research. As suggested by Chin and Chia (2006) such scientific thinking processes can be developed in students with the integration of the problem based learning (PBL) into the curriculum. In fact, the PBL provides students with guided experience in learning through dealing with ill-structured problems based on real life. Ill-structured problems are complex problems that have multiple solutions instead of having a single correct answer, and to generate a solution and support their ideas students need to consider alternatives by using personal opinions and provide a reasoned argument (Hmelo-Silver & Barrows, 2006; Jonassen, 2000). Actually, three major components of a PBL environment include presence of ill-structured problems, teachers as facilitators, and changed students‘ role in learning (Curry, 2002). Firstly if we take a look at the problems we can see that unlike well-structured problems which focus on conclusion with straightforward solutions, ill-structured problems incline students in a messy situation with no one right answer and allow creation of several hypotheses and solutions (Levin, 2001; Sage, 1996).

These problems play a role as a ―content and knowledge organizer, learning environment contextualizer, thinking reasoning stimulator, and learning motivator" in the PBL process (Hung, 2006, p.56). Therefore, since the problems are ill-structured, the PBL students are to define the problem and determine what they need to know. Moreover, ill structured problems based on real life situations help students make connections with real world and realize that what they learn in the classroom can be used in their daily lives (Levin, 2001). Additionally, these problems allow students to take the responsibility of learning and increase their activity in the learning process by giving roles, to play according to scenario. This situation is not only enjoyable but also helps students define the problem. Therefore, in PBL environments ill-structured problems are used as guides for student learning, and teachers, who are no longer considered as dispensers of knowledge, are expected to keep students on track while they decide on what directions to follow in their investigations, what information to collect, and how to evaluate the information (Chin & Chia, 2004; Hmelo-Silver, 2004; Song, Grabowski, Koszalka & Harkness, 2006).

Accordingly, in a typical PBL class, lesson starts with meeting the problem but the students are to be prepared for PBL process. In fact, the steps of PBL was specified by Torp and Sage (1998), in the following order; prepare the learners, meet the problem, identify what we know, what we need to know, and ideas, define the problem statement, gather and share information, generate possible solutions, determine the best fit of solutions, present the solutions, and lastly debrief the problem. More specifically, in a PBL class the students need to know how a PBL lesson runs on and what they are going to do in this process. When they meet they take roles to play and identify what they know, generated ideas, hypothesis and determine learning issues (Hanson, 2006). They conduct independent study after lesson. They revise their hypothesis and ideas in line with new information (Robins & Pals, 2002). Based on information and ideas, they generate possible solutions to the problem and choose the best one. Because the problems are ill-structured they need to generate plural hypothesis. The important point is not to find a correct answer; but to learn the content while acquiring the information individually, sharing and exchanging and integrating them with peers. All groups present their solution and explain their process through PBL lesson. During these processes, the teacher guide students to reach right sources and try to keep them on track (Robins & Pals, 2005).

The other major features of PBL contain a change both in teacher and student role in learning. In a PBL environment, students are challenged to understand the problem situation, identify important points to be investigated, formulate hypothesis for a solution, access a variety of resources to gain new knowledge, think about how this new knowledge can be used to deal with the problem, and reflect on their understanding. Moreover, in a PBL class students participate in social interactions working in groups and the teacher acts as a facilitator. Therefore, in PBL classrooms, students‘ role changes from passive knowledge receivers to active learners and teachers‘ role changes from knowledge transmitter to facilitator in the learning process. In other words, instruction is students centered not teacher directed in the PBL (Levin, 2001). The PBL teacher as a facilitator scaffolds students‘ learning by clearing misapprehensions and gives clues through questions, and produces good strategies for learning and thinking rather than giving the subject directly (Hmelo-Silver & Barrows, 2006). Moreover, teachers are expected to make students more responsible for their learning (Achilles & Hoover, 1996). They are to follow up the students‘ progress and guide them. Rather than transferring knowledge, they facilitate the learning (Fyrenius, Bergdahl, & Silén, 2005). In addition, feedback to students as well as facilitation required from teachers. The teacher checks on the students in each group and help groups clear up misconceptions or help them keep continue to learn in the right way (Mckeachie, 2007).

According Torp and Sage (2002), ~~"as~~ teachers model and coach strong cognitive and metacognitive behaviors and dispositions, students learn how to learn and become excited about learning through problem solving." (p.34). In addition it should be noted that, implementation of the PBL involves both cooperative learning and independent learning. Cooperative learning, which provides students with opportunity to learn while working in small groups, is one of the best ways for active learning (Silberman, 1996). Similarly, Rivarola and García (2000), considered that team work is the best way to encourage student participation and interaction, discussion, corporation and conceptual communication. PBL favours learners to work with group peers and share their findings and ideas to reach the solution. Besides, it develops students' skills to become self-directed learners by requiring students to work in a group cooperatively to get information to decipher the problem. On the other hand, while learning on their own independently, students take the responsibility of learning and are expected to assess their performance in order to determine what they need to learn (Burgess, 2004) .

Searching information and deciding what is going to be learned becomes personal construction of the learner. In a PBL classroom, after defining the problem and determining the needed information for finding them, students search the resources like library, books, internet, and e-sources individually then share the information in their group. Savery and Duffy (1995) supported the claim that PBL is a constructivist approach and is agreed with the principles of constructivism. The principles are as follows. Firstly, the purpose of the learning activities should be clearly perceived and accepted by the learner. Since the goals of the learners determine what they learn, a task should be established in a way that learners may adopt it as their own. Secondly, similar to the first principle, students should be encouraged to take on the ownership of the process used for the task. Thirdly, authentic tasks and complex environments should be generated for students. These tasks and learning environments should be challenging for learners' thinking skills. Fourthly, teachers' roles in instruction should be to support effective functioning of learners in complex environments, to encourage their alternative views, their discussions in the collaborative learning groups, and to encourage testing their ideas and hypotheses. Lastly, the evaluation should be based on learning process as well as the concepts learned. Savery and Duffy suggested that abovementioned characteristics are all relevant to PBL instruction.

In fact, according to Arambula-Greenfield (1996), PBL is an instructional format that requires students to participate actively in their own learning by researching and working through real-life problems to arrive at a best solution. In the PBL process, the problems are the center of the learning. The problem is given students at the beginning of the process and learning occurs by doing the problem solving (Burgess, 2004). Problems aim at to motivating students to learn and providing a real world context to examine the related issues(Savoie & Hughes, 1994). The problem is ill-structured that is unclear and open-ended and that raises questions about what is known, what needs to be known, and how the solution can be found (Greenwald, 2000). Problems have many solutions ways and individuals solve them by influencing their vantage point and experience (Greenwald, 2000).

Since the problem is unclear, students need to redefine the problem as new information is gathered (Greenwald, 2000) and to eliminate some of the hypothesis or to generate new ones. In typical classroom problem solving approaches, students encounter problems after they learn the required content knowledge (Uyeda, Madden, Brigham, Luft, & Washburne, 2002) and when all information needed for solution building is available (Greenwald, 2000). On the contrary, in PBL approach learning begins at the introduction of problem to students. The process is regulated by students as generating hypotheses to the problem based on the information in the problem, their prior knowledge and research.

2.4 Goals of Problem – Based Learning

❖ **Development of effective self-directed learning strategies**

Self-directed learning makes the student aware of the importance of personal learning needs. Additionally, it allows him to find and to utilise accurately all kinds of information resources (Norman & Schmidt, 1992). According to Torp and Sage (1998) metacognitive strategies are important for developing self-directed, lifelong learning skills. These are the skills that enable autonomous learning. First, learners must have a metacognitive awareness of what they do and do not understand. Second, they must be able to set learning goals, identify what they need to learn more about for the task they are engaged in. Third, they must be able to plan their learning and select appropriate learning strategies. In other words, they must decide on a course of action to reach these goals. Finally, as they implement their plan, learners must be able to monitor and evaluate whether or not their goals have been attained.

❖ **Increased motivation for learning**

Since students will perceive the problems studied as relevant and given that sessions are structured as open-ended discussions, curiosity is fostered. (Norman & Schmidt, 1992).

❖ **Becoming effective collaborators**

The PBL process pushes students to work together and to help each other to get an understanding of what they are learning and its relevance to the problem. It is this collaboration that permits the students to build up the abilities necessary to be responsible for their own learning. Collaboration is an indispensable ability that students should have, since they will be regularly working as members of teams (Hmelo-Silver & Eberbach, 2012). Research literature has shown that the success of problem-based learning depends on group work (Gallagher, Sher, Stepien, & Workman, 1995). From the objectives highlighted above, it is clear that the principal goal of the PBL approach is the development of higher order thinking. PBL main objective is to stimulate students to learn at the higher levels, where students analyze, synthesize and evaluate instead of simply know, comprehend and apply (Guedri, 2001).

2.5 Characteristics of Problem Based Learning

PBL is a pedagogical strategy for posing significant, contextualized, real world situations, and resources, guidance, and instruction are provided to learners as they develop content knowledge and problem-solving skills to come up with tentative solutions to the problem (Mayo, Donnelly, Nash, & Schwartz, 1993). PBL begins with the assumption that learning is an active, integrated, and constructive process influenced by social and contextual factors. PBL is characterised by a learner centered approach. PBL teachers work as facilitators who mainly provide scaffolding guidance in the learning process rather than being disseminators of knowledge. Also, open-ended/ill-structured problems are seen as the preliminary motivation and framework for learning (Wilkerson & Gijselaers, 1996). In PBL, facilitators are encouraged to promote learners‘ intrinsic interest in the subject matter, emphasise learning as opposed to recall, promote group work, and help students actively engage in the process of finding additional learning resources to solve the given problem so that they will become self-directed learners. The ―student-centered" approach allows learners to study those topics that interest them the most, and decide how they want to undertake the work. According to Torp and Sage (2002) PBL is a strategy that is student-centered, in this methodology students research, explain, and cooperate in order to find meaningful solutions to real life problems.

Gallagher (1997) Reynolds (1997) asserts that learners should identify their learning needs, help plan classes, lead class discussions, and assess their own work and that of their classmates. According to Gijselaers (1996), PBL requires students to be metacognitively aware. This means that learners must identify what information they already know about the problem, and decide what information they need to know to solve the problem. This helps learners become more effective problem-solvers and self-directed learners. According to Arambula-Greenfield (1996), instructors must play their role as a tutor or cognitive coach who models inquiry strategies, guides exploration, and helps students clarify and pursue their research questions. One of the important features of PBL is group work. This helps develop learning communities in which students feel comfortable developing new ideas and raising new questions about the material (Allen, Duch, & Groh, 1996). Moreover, group work increases communication skills and students‘ ability to manage group dynamics. It is also motivating for learners, because they become actively involved in the work and are held accountable for their action by group members. However, groups are not always effective without the instructor‘s guidance because many group members have not been trained in group work skills. For this reason, the teacher will often need to facilitate group interactions (Cohen, 1994).

Furthermore, in PBL lessons students should be allowed to work within their groups to solve their assigned problem under the teacher's facilitation. It is therefore important the teacher guides students on how to work in groups and explain the roles that group members can take, such as the selection of the group leader, the recorder or the reporter for the group. These positions can be rotated amongst the group members after each problem so that every group member has equal opportunity to play the leadership role. Group work is an important factor in the implementation of a PBL approach as learning through group work helps students achieve the expected outcomes such as skills of self-directed learning, team-working, problem-solving and leadership.

2.6 Implementing Problem-Based Learning in the Senior High School Chemistry Education

Chemistry is one of the natural science's branches and one of the most important sciences to be studied. Based on global and historical views, all aspects of daily life such as food, drink, clothing, medicine, housing, vehicles, etc. are related to chemistry. Chemistry contributes in helping people to solve complex life problems. Chemistry explains a lot about the phenomena that occur in everyday life, this means that chemistry cannot be separated from life. To get the benefits of chemistry then the chemistry must be studied since in the junior level and then continued in high school. Studying chemistry from different stages experiences different levels of knowledge tailored to the learner's educational stages. Through chemistry, we recognize the composition of substances and the use of chemicals, both natural and artificial, and recognize important processes in living things, including our own bodies. Chemistry concepts that become difficult and error in the learning is a core concept and a basis for further chemistry study or supporters of the natural science and other branches. In fact, it is found that many students who study chemistry are not interested and have no understanding after studying chemistry (Alkan, 2016;Tarhan & Sesen, 2013).

The difficulties of studying chemistry in senior high schools are caused by obstacles to support competencies in mastering concepts, on learning process and on students‘ environmental factors. PBL process start with real world problems; its contents and practices must be attractive to students. The Students must be encouraged to have adequate time to collect information and set strategies of solving problems. PBL enable students see events across disciplines. Although teachers have difficulty to change teaching styles and it is time consuming. PBL engages students to learn through presentations and interactions in groups and places more responsibility of comprehension on them; this improves their learning and development of problem solving skills, thus translate into higher students achievements. PBL is very effective in enhancing student achievement in chemistry and it is gender friendly as both male and female showed equally improved achievements. PBL has effect on student achievement." Therefore it is more effective than lecture method. PBL strategies are connected to students ‘future careers, it encourages them to search for solutions to the problems in class rooms and everyday lives. This enables them understand the connection between science classes and situation in the society, hence they develop interest, positive attitude towards learning and achievement.

2.7 The Relevance of PBL in the Science Classroom

According to Sternberg (1998), ―instruction should be geared not just toward imparting a knowledge base, but toward developing reflective, analytical, creative, and practical thinking with a knowledge base. Students learn better when they think to learn. They also learn better when teaching takes into account their diverse styles of learning and thinking" (p. 11-20). The essence of learning is, learning how to learn and learning how to think in order to meet the demands of the 21st century. However, conventional learning approaches which are content-driven have been dominant in most classrooms in traditional senior high school education. These traditional approaches were seen to be appropriate approaches in the past for preparing senior high school students for their future tertiary education. These conventional methods of instruction have been found to not fully prepare students with the skills and attributes they require in their future learning environments.

The best way for students to learn science is to experience problems that challenge science, and the thought, habits of mind and actions associated with trying to solve them. This implies opportunities for authentic, inquiry-based learning. Problem-based learning (PBL) is a powerful vehicle for this, in which a real-world problem becomes a context for students to investigate, in depth, what they need to know and want to know (Checkley, 1997). It is a robust, constructivist process, shaped and directed primarily by the student, with the instructor as metacognitive coach. PBL is not just another iteration of what many science educators already use in their classrooms. To be truly "problem-based", Gallagher (1995) emphasizes, all three of these key features must be present: initiating learning with a problem, exclusive use of ill-defined problems and teacher as metacognitive coach. Conventional methods use in teaching science often fail to motivate students in the learning process or support them to become active learners.

However, these traditional approaches are still being widely used today in the senior high school science classrooms. Conventional approaches which had been used for a long time in senior high school education has been recognized as limiting students to be good problem-solvers and self-directed learners in science in this information age. The theme of science education reform is to understand science as ways of thinking and doing as well as bodies of knowledge. In the science classroom learning is best achieved when the learner is the one who looks deeper to create meaning and develop understanding. The science classroom should be the one which will allow learners to become thinkers and problem solvers and habits of mind that promote exploration and discovery such as curiosity, questioning, openness to ideas, learning from errors and persistence. Learning in the science classroom needs to occur in the context of real investigation through inquiry and reasoning, which means teaching for understanding not memorization of facts. Prince and Felder (2006) argued that PBL is one of the inductive teaching methods which come in a variety of forms such as discovery learning, inquiry-based learning, problem-based learning, project-based learning, case-based teaching and just-in-time teaching. In the inductive form of teaching, the teacher begins by introducing a learning challenge to learners, such as a case study to analyse, or an ―ill structured" problem to solve.

The learners faced with the learning challenge will search for facts, skills and conceptual understanding to solve the learning problem under the teacher‘s facilitation and guidance. PBL in the science classroom will allow educators to connect science with real world contexts and enables learners to solve complex problems and become independent learners.

2.8 The Teaching and Learning Methods used in teaching of Chemistry

The way in which students approach their learning in chemistry is undervalued in most senior high schools in Ghana. Many of the traditional methods of teaching chemistry originated from scientific practices of the late nineteenth and early twentieth centuries. During this time, chemistry at the professional level dealt with analysing and classifying substances as well as understanding their properties and structure. In modern times, the work chemists do is more diverse and applied as they apply their knowledge in the field to develop new products and technologies to monitor and understand the world around them.

The problem of poor performance of students at the senior high school in chemistry is a great concern to chemistry educators and relevant stake-holders in education. As accepted throughout the world the idea of using student centred constructivist based instructional methods is widely accepted, since teacher centred and traditional instructional methods has given insufficient opportunities for student to construct their own learning. Eliciting students' individual capabilities, intelligence and creative thinking can only be achieved through student centered instructional methods. According to Wachanga and Mwangi (2004), successful teaching and learning of Chemistry depends partly on methods whose activities target most learning senses. This may imply that there is need for teachers to vary the teaching technique in their day to day teaching activity. In Ghana, most senior high school Chemistry students have inadequate knowledge of the fundamental principles which underpin the study of chemistry. It is highly commendable that chemistry teachers should try to help students incorporate their learning styles and approaches when they learn chemistry ((Rollnick, Davidowitz, Keane, Bapoo, & Magadla, 2008).

Chemistry as a subject at the senior high school do not only incorporate basic general disciplines of mathematics, physics and chemistry but they also involve the following chemistry disciplines: physical chemistry, organic chemistry, inorganic chemistry and analytical chemistry. Adesoji and Olatunbosun (2008) carried out a study on student, teacher and school environment factors as determinants of achievement in senior secondary school Chemistry in Oyo state. Nigeria. In this study they observed that Chemistry teaching can only be result- oriented when students are willing and teachers are well disposed using the appropriate methods. They further stated that there is much more demand and emphasis should be laid on the teacher, the learner, the curriculum and the environment in the whole process of teaching and learning of science. The teaching approach that a teacher adopts is one factor that may affect students‛ performance,(Mills, 1977).

The teaching of the contents in chemistry should promote students' capability to design their own scientific experiments. That capability requires a higher order understanding of the concepts that make up accepted theories. Also Danili and Reid (2004) studied difficulties facing the majority of Greek pupils in understanding Chemistry concepts, and therefore performing well in the National Examinations. Their purpose was to explore the problems and to suggest ways in which the situation might be improved. They suggested that approaches to learning must take into account cognitive factors in the learners in the context of information processing and understandings. If this is done, learning is much more effective. One of the major aims in teaching chemistry at the Senior High School should be the one that will help learners develop critical thinking ability to understand and make decisions about issues they may face in their everyday lives outside the classroom, teachers can thus better prepare students for the modern world by teaching with a novel approach. Consequently, any instructional process that fails to achieve understanding of concepts should be considered ineffective.

2.9 Inquiry-Based Learning

In the same way that scientists develop their knowledge and understanding as they seek answers to questions about the natural world, students develop an understanding of the natural world when they are actively engaged in scientific inquiry - alone and with others. Investigative work has enormous benefits. Students have autonomy over their work, they must use research, solve problems and if necessary, set out in new directions and in the end, try to make sense of their results. They develop practical skills, attitudes of resourcefulness, perseverance, and enterprise. Educators focus inquiry dominantly on real phenomena, in classrooms, outdoors, or in laboratory settings where students are given investigations or guided toward fashioning investigations that are demanding but within their capabilities (Kelly,2005).

2.10 Gender and Students' Achievement in Chemistry

The issues of access to science education have been a major concern worldwide with disparity in gender attracting more attention in recent times. Globally, disparities in literacy between males and females remain everywhere although they have narrowed considerably since 1970s (Holland-Cunz & Ruppert, 2002). The influence of gender difference on students' level of achievement has been a matter of concern to science educators. In a developing country like Ghana, Science Education can be considered one of the mean to ensure progressive and durable development with both male and female participating equally. Ghana had made frantic efforts by spending huge sums of money and resources to ensure that development take place in all parts of the country. The developmental approach of ―Sustainable Human Development (SHD)‟ emphasizes on the participation of all segment of the population aiming to extirpate imbalance between sexes with respect to education, economy and health. In spite of the fact that improvement and making of science education accessible to all has been a major aim of African governments since 1960s, the history of science education to date has been a catalogue of enduring an existing inequalities between boys and girls, men and women. Umoh (2003), defines gender as a psychological term used is describing behaviours and attributes expected of individuals on the basis of being born as either male or female. Okeke (2003) specifically notes that the study of gender means the analysis of the relationship of men and women including the division of labour, access to resources and other factors which are determined by society as opposed to being determined by sex. Gender is a major factor that influences career choice and subject interest of students. In our societies, more difficult tasks are usually reserved for males while less difficult ones are considered feminine in a natural setting. Example of this is weeding, which is often seen as manly task while washing of clothes could be seen as a female task at home. Thus at school males are more likely to take difficult subject areas and challenging problem-solving situations while female on the other hand prefer simple subjects and often shy away from difficult tasks and problem solving situation.

It is obvious that the Ghanaian culture regards male as superior to their female counter parts, thus gender-role differentiation is very much pronounced in our society. This places a very serious constraint on the academic performance of male and female students in chemistry because role differentiation or distinction limits the full participation, development and utilization of individual potentials either directly or indirectly. Even as access to science education in Ghana clearly put the female student at the disadvantage side, another worrying phenomenon is belief and dispositions that tends to view chemistry as a male domain and which perpetuates the idea that males are naturally more chemistry inclined. This is true because girls who do well in chemistry are referred to as boys. The researcher is of the affirmation that students, irrespective of their sexes, possess the abilities to make significant achievements in chemistry when provided with the appropriate learning approach as well as support and environment. In a study conducted by Ajayi and Ogbeba (2017) on ―Effect of Gender on Senior Secondary Chemistry Students' Achievement in Stoichiometry Using Hands-on Activities, it is evident from the findings of this study that no gender disparity exists in the achievement of male and female chemistry students taught stoichiometry using hands-on activities. Also a study conducted by Udousoro (2011), on The effects of gender and mathematics ability on academic performance of students in chemistry. The findings from the study indicated that gender does not have effect on students‘ performance in chemistry whereas mathematics ability has. In a study conducted by Okeke (2018), on Interaction effect of gender and treatment on mean retention score of chemistry students taught using mend mapping teaching strategy (MMTS) in Enugu. The study shown that MMTS has significant effect on students‘ cognitive retention in Chemistry. Whiles the influence of gender on mean retention score was not significant. The above studies give a clear indication that gender has no effect on a teaching method applied in teaching chemistry.

In Ghana there has been recurring arguments on the interacting effect of gender and treatment on mean retention score of chemistry students taught using different teaching strategies, researches have been carried out on treatment interaction in order to ascertain the best teaching strategy most especially in the field of pure sciences, but most results have been inconclusive, or proven wrong due to the recent performances of the students. Therefore, there has been a difficulty in ascertaining the existing treatment interactions, and also determining a suitable teaching strategy in the field. Treatment interaction generally implies that different learners with different characteristics may profit more from one type of instructional method than from another and that therefore the researcher strongly affirm that problem-based learning if properly applied helps improve students‘ cognitive achievement irrespective of their gender.

2.11 Teacher-Centred Method of Teaching Science

Conventional, teacher-centred instruction generally is seen as an information transfer from the teacher to the learner (Bonk & King, 2012; Kember & Gow, 1994).This type of teaching methods focus on telling, memorizing, recalling information. The students' participation is very limited where they only ask questions or answers questions. Most of the time the students are passive listeners and receive the knowledge. The teacher is the center of the learning process that goes on in the classroom. In teacher-centered learning, teachers play important roles in the learning process. Teachers are information providers or evaluator to monitor students to get the right answers, yet students are viewed as learners who passively receive information. In a traditional classroom, students become passive learners, or rather just recipients of teachers' knowledge and wisdom. They have no control over their own learning. Teachers make all the decisions concerning the curriculum, teaching methods, and the different forms of assessment. Duckworth (2009) asserts that teacher-centered learning actually prevents students' educational growth.

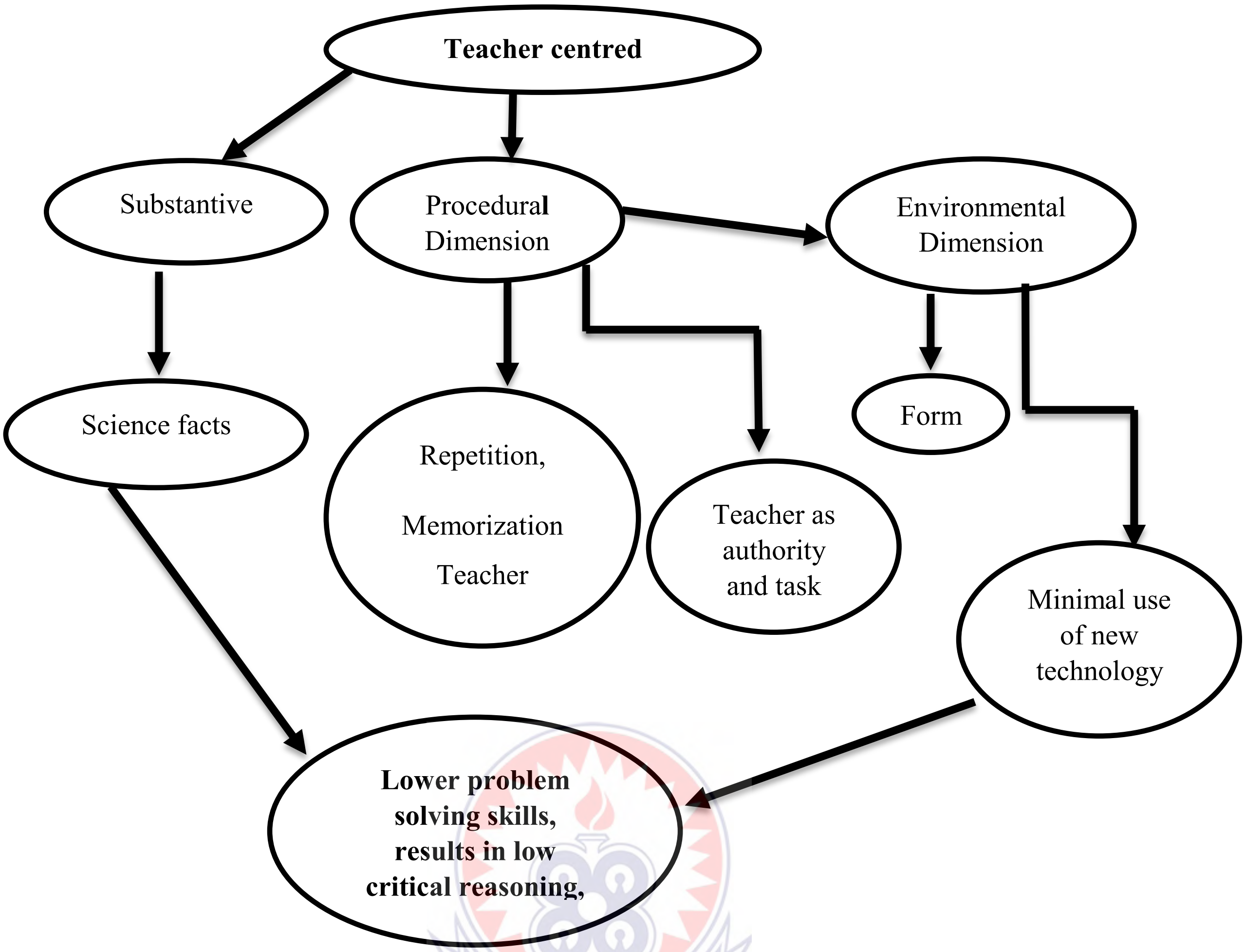

Fig 1: A Teacher - Centred Approach of Teaching Science (Yadav et al., 2014)

2.12 Student-Centred Approach of Teaching Science

Although a foundational shift from a traditional classroom, a learner-centered approach does not eliminate the teacher. A learner-centered environment facilitates a more collaborative way for students to learn. The teacher models instructions and acts as a facilitator, providing feedback and answering questions when needed. It‘s the student that chooses how they want to learn, why they want to learn that way and with who. Students answer each other‘s‘ questions and give each other feedback, using the instructor as a resource when needed. This process allows students to become owner of their knowledge. Taking into consideration what works for one may not work for another and at the end of the day it‘s not about what was taught but what was learned.

In contrast, in a learner-centered classroom, students are actively learning and they have greater input into what they learn, how they learn it, and when they learn it. This means that students take responsibility of their own learning and are directly involved in the learning process. Learner-centered teaching style focuses on how students learn instead of how teachers teach (Weimer, 2002). Instruction is most suitable for the more autonomous, and more self-directed learners who not only participate in what, how, and when to learn, but also construct their own learning experiences. This process emphasizes on need, requirement, interest and capability of students. The students are active participants where their skills and abilities are developed. Teacher and students jointly explore the different aspects of problem. The role of the teacher in to create a problematic situation, have materials and resources available to the students, and help them identify issues, state hypotheses, clarify and test hypotheses and draw conclusions.

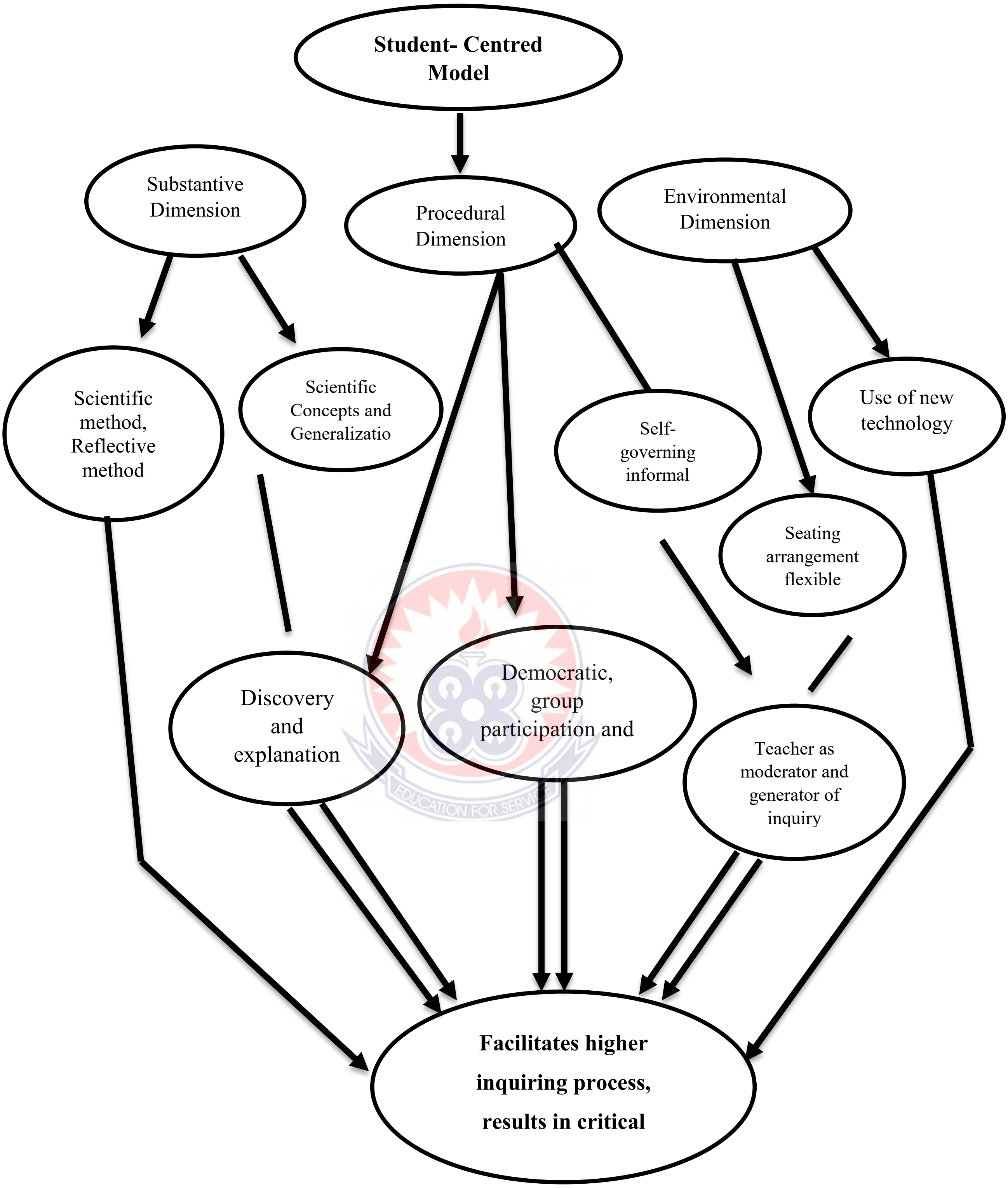

Fig 2: A Student- Centred Approach of Teaching Science (Yadav et al., 2014)

2.13 The Relevance of Teaching Method in Science Education

There are different teaching methods employed in science education in the Ghanaian senior high schools. Miles (2015) asserted that it is expected of a teacher to implement a range of instructional strategies that will bring academic success to all the science students. For any method to be able to bring good result in the present age, it should be a method that promote maximum social interaction. Social interaction between students and between teacher and student plays a crucial role in learning (Nguyen, Williams, & Nguyen, 2012). The teaching methods commonly used in science education classes is the traditional method where science teachers directs students to learn through memorization and recitation techniques thereby not developing their critical thinking problem solving and decision making skills. Science education is vital to the pace of the social, political and economic development of any nation, so effective teaching is very essential. Effective teaching in science is important because teaching is based on helping children progress from one level to another in a more sociable interactive environment and to get the approach right to get students to be independent learners (Muijs & Reynolds, 2017).

The teaching of science requires clear goals and non-traditional models that use the *inquiry* processes-exploration, based on the natural curiosity of human beings-to promote the development of skills associated with scientific culture. Through these active learning strategies, the objective is to promote the understanding of basic concepts by students, as an indispensable requirement to understand the fundamental theories of science. The learning of science should be the one that will generate conceptual understanding as students develop the ability to adequately recognize, interpret, explain, and illustrate the connections among the subordinate concepts of a macro concept and among these with other related concepts. Science teachers need to recognize the nature of the scientific endeavor and how it relates to science teaching if they are to help students completely understand the content and underlying philosophy of science (Hodson, 1988, 1991; Matthews, 2014).

This recognition is necessary because the portions of scientific knowledge science teachers choose to teach and how they carry out the instruction present a particular view of the nature of science to their students. Selecting primarily content that can be logically deduced from classroom experiments is likely to leave the impression that science is limited to hypothetical-deductive experimentation that immediately leads to scientific laws. Berry (2008) argued that traditional method like lecture approach lacks the effectiveness of an active learning approach. In this era of instant and global information access, it has become increasingly important for science teachers to help students develop science process skills instead of focusing solely on the memorization of a body of facts. Science should be a verb instead of a noun." It is therefore incumbent on science teachers to use innovative teaching methods rather than relying on traditional methods which only results in rote memorization of scientific concepts.

2.14 Empirical Studies on PBL in Chemistry

Many researchers have affirmed successful implementation of problem-based learning in the classroom. Cockrell, Caplow, and Donaldson (2000) concluded that there was increased in student‘s perception of PBL instruction since it enables them to fosters transfer of knowledge. PBL is effective compared to other pedagogical approaches since it facilitates student‘s critical thinking and problem-solving skills, since students are able to apply theory into practice (Cooke & Moyle, 2002). Studies on PBL in medical education have shown that PBL helps students apply and integrate knowledge more effectively, and increases their motivations and attitudes toward learning (Albanese & Mitchell 1993; Schmidt & Moust 2000).

Many researchers have begun to interest in using PBL in the other disciplines including high school education (Gallagher, 1997). PBL method has recently been applied in many branches of science especially in chemistry education (Dods, 1996; Ram, 1999; Mackenzie, John stone & Brown 2003; Yuzhi 2003; Kitto & Griffiths; 2001). Owusu (2020), conducted a study to determine the effectiveness of problem-based learning (PBL) approach to mole concept among students of Techiman Senior High School. The study used pre-test post-test quasi-experiment experimental design. The study considered seventy-four (74) second year students offering General Science Programme consisting of 37 students in the control group and 37 students in the experimental group. In the study, the experimental group were introduced to the Problem-based learning approach whiles traditional lecture-based method was used in the control group. The results of the study revealed that the PBL resulted in significantly higher students" achievement in mole concept than the traditional lecture method. Problem-solving is the highest form of learning (Adeyemi, 2008).

According Kelly and Finlayson (2007) PBL sees a shift in educational focus from a teacher-centred approach to teaching and learning to a student-centred one, whereby students construct meaning for themselves by relating new concepts and ideas to previous knowledge. PBL is an instructional approach that helps in finding solutions to many of the limitations of conventional methods by teaching important concepts in the context of solving real analytical chemistry problems. In a study by Yuzhi (2003), he aimed to teach chemical analysis and instrumental analysis in analytical chemistry through PBL. The results indicated that students in the PBL groups were much more successful in the use of laboratory equipment, producing solutions to the problems, self-efficacy and theory production. It was also asserted that the students developed positive attitudes towards chemistry when they were taught through PBL.

Also, Ram (1999) and Ying (2003) conducted PBL research in analytical chemistry. The results they obtained indicated PBL prepares students in tackling everyday life problems and engages them in learning information. In the other study, Senocak Senocak, Taskesenligil, and Sozbilir (2007) compared the achievement of prospective primary science teachers in a problem-based curriculum with those in a conventional curriculum. Their results indicated that PBL is effective on students‵ learning about gases, and on increasing positive attitudes towards chemistry, on development self-directed learning, cooperative learning and critical thinking. In a study conducted by Groh (2001), it was found that PBL in a general chemistry course is effective on students‵ understanding of the principles of solutions and their properties. Tarhan and Acar (2007) also conducted a study on the effects of PBL on high school students‵ understanding of ‗the effects of temperature, concentration and pressure on cell potential‵ and also their social skills. The study employed pre-test post-test quasi experimental design with twenty (20) students in both the control and the experimental group. A teacher-centered traditional format was used for the control group, and a PBL formasst for the experimental group. Results from the study showed that PBL is effective on students‵ achievement, remedying formation of misconceptions, where the students taught with PBL were more active in cooperative group activities than the traditionally-taught students.

Tarhan, Ayar-Kayali, Urek, and Acar (2008) also examined the effectiveness of PBL on 9th grade students‵ understanding of intermolecular forces (dipole– dipole forces, London dispersion forces and hydrogen bonding. The study employed pre-test post-test quasi experimental design consisting of seventy-eight (78) 9th grade students.

Forty (40) students in the experimental group and thirty-eight (38) students in the control group. Students in the experimental group were taught using PBL instruction whiles student in the control group were also taught using lecture method of instruction. Results from the study indicated that PBL is affective on students‘ achievement, remedying formation of alternate conceptions and also social skills.

In a study by Tarhan and Acar (2007) to investigate the effects of Problem based learning on high school students‘ understanding of ionization of water and acid and base strength. A pre-test post-test quasi-experimental design was employed in this study. One hundred and eight (108) high school students in four classes in two schools in Izmir, Turkey was used in the study. There was one experimental (nE-1=21, nE-2=32) and one control (nC-1 =24, nC-2=31) groups in each high school, which were stratified randomly. Students in the experimental groups were instructed via Problem based learning, whiles teacher-centered approach was used for the students in the control groups. The results from the study confirmed that PBL is an active learning approach and have positive effects on higher learning achievement, overcoming alternative conceptions, and development of some social skills. PBL helps students to improve critical thinking skills after discovering a problem on their own and finding solution to them. This is because they develop positive attitudes towards learning and problem solving abilities, which they are exposed to. PBL allows learners to evaluate and infer into contents learnt while making reasonable conclusion. With this, a habit of mind is promoted among students, which increases scientific literacy among learners.

Charif (2010) also carried out a research to investigate the effects of problem-based learning in chemistry education on middle school students‘ academic achievement and attitude on 7th grade students, in a private school in Lebanon. In the study, data was obtained through the use of pre-test post-test, research-control group model. A total of 53 pupils participated in the study; they were divided into two groups, an experimental group that consisted of (26) students and a control group that consisted of (27) student. PBL approach was applied on the experimental group whiles the students in the control group were taught using conventional learning strategies. Results from the study indicated that implementing problem based learning approach had improved students' achievement and attitude. Abanikannda (2016) also carried out a research on the influence of problem-based learning in chemistry on the academic achievement of high school students in Osun State, Nigeria. The study adopted a descriptive survey design with 300 students comprising of high School form two students of Osun State in Nigeria. Results from the research in which PBL approach was compared to the conventional learning revealed that PBL approach was more effective in terms of students' achievement towards Chemistry.

Aidoo, Boateng, Kissi, and Ofori (2016) conducted a study on the effect of Problem-based -Learning on students' achievement in chemistry. Pre-test, post-test control group quasi-experimental design was employed for the study. One hundred and two (102) equivalent students were selected for the study consisting of fifty one (51) students in both the control and the experimental group. The control group were taught with traditional lecture method whiles the experimental group received instruction with PBL. The results indicated a significant statistically change and positive evaluation in favour of the problem-based learning approach to traditional method of transmitting of learning, giving an indication that, PBL is an effective way to teach chemistry so as to improve students' critical thinking and problem solving skills as well as their thinking abilities. A good instructional strategy should motivate students to make them understand and reflect on what content they have been exposed and help to develop their critical thinking and problem-solving skills Tretten and Zachariou (1995). Valdez and Bungihan (2019) also carried out a study aimed to investigate the effectiveness of problem-based learning (PBL) approach in enhancing the problem solving skills in Chemistry of Grade 9 students in a public high school in the Philippines.

The study used the descriptive-comparative and pretest-posttest experimental design on ninety six (96) students. In the study the level of problem solving skills of the students in the non-PBL and PBL group before and after their exposure to non-PBL and PBL approaches was determined respectively. The comparison of their levels before and after the intervention was done to determine the effectiveness of the non-PBL and PBL approaches. Then comparison of the effectiveness of non-PBL and PBL approach was assessed. The following conclusions were drawn from their study

1. The level of problem solving skills before and after their exposure to non-PBL approach is generally very low.
2. The level of problem solving skills was initially very low but was comparatively increased to low after exposure to PBL.
3. There was a significant difference in the level of problem solving skills of the students in the PBL group.
4. Between these two approaches in this study, the PBL approach of teaching the chemistry concepts to Grade 9 students was proven more effective than the non-PBL approach. Problems related to everyday life and semi-structured problems are posed due to the fact that they help any knowledge gained to become permanent.

In PBL, students gain problem-solving skills, work in collaborative groups, and increase their self-confidence and this method provides an impetus to students for self-learning and permanent learning (Hung et al. , 2008).

Günter and Alpat (2017) also carried out a research on the effects of problem-based learning (PBL) on the academic achievement of students studying ‗Electrochemistry'. The research used a pretest–posttest control group quasi-experimental. In the research, Subjects were randomly assigned to the experimental and control group. The topic was taught with PBL in the experimental group and with expository teaching strategies in the control group. The conclusion from the study indicated that the students in the experimental group were better able to understand the topic and its structure compared to the students in the control group. Also the students in the experimental group had positive opinions regarding PBL.

Sarigoz (2012) indicated that, due to problem solving approach; a student is not only able to learn the basic concepts but also can apply in the real-life scenario. The superiority of problem based learning strategy over the conventional method also known as the traditional lecture-based could be attributed to the logical and sequential manner with which instructions are presented in problem based technique and practical skills teaching (Raimi & Adeoye, 2012).

2.15 A Problem -Based Learning and Science Achievement

When the aims of science education are examined, it is seen that the problem-based learning is quite appropriate for realization of these aims (Tobin, 1986). Today, many science educators considering this importance have increasingly started to apply problem-based learning approach in science education (Lazear, 1991; Peterson & b, 1998; Slavin, 1999; Greenwald, 2000; Yuzhi, 2003; Şenocak, 2005). PBL with its constructivist roots ties in naturally with science education. Driver et al. (1994) strongly argued for a constructivist approach to science education: ―The view that knowledge cannot be transmitted but must be constructed by the mental activity of learners underpins contemporary perspectives on science education" (p. 5).The level of science education is one of the measures of growth of any nation (Nwachukwu & Ogbo, 2012).

Student's ability to make connection with real life situations is important as these abilities are needed by their employers. The present science curricula of Ghana being implemented are always criticized of not producing students with enough experience and skills to solve problems and challenges of the imagined global trends. The basic aim of education is to enable individuals become effective problem solvers. It is therefore important for students to face real problems in their learning environment and proffer appropriate solutions to these problems. The most convenient approach for achieving this in learning environments is the use of student-centered approach of learning such as the problem-based learning (PBL).The facts that science education is based on both practice and interpretation, that it is so connected with real life and that it requires cooperation facilitate the problem-based learning practices. Many researchers (Dods 1996; Ram, 1999; Mackenzie, John stone & Brown 2003; Yuzhi 2003; Kitto & Griffiths 2001, Owusu, 2020) have investigated learners ―achievement in science through problem-based learning. These researchers' findings indicated that learners can explore problem situations and ―invent" ways to solve the problems. For instance, in the United States of American (U.S.A) number of studies and reports within the last decade have called for changes in science instruction (American Association for the Advancement of Science, 1997; National Science Teachers Association, 2003).

One of the many recommendations has been for science instruction to give students greater opportunities to work in collaborative groups (Blumenfeld et al., 1991). According to Boaler (2002), students that enrolled in problem-based learning attained a higher grade in national examinations in United Kingdom (U.K) and that significant number of three times students taught through a problem-based school passed the national standardized examination than traditional school students. These findings confirmed that problem-based learning has significant impacts on students' problem solving skills and attitudes towards learning. One key question that needs addressing when talking about learning science through a problem-based learning approach is whether learners can explore problem situations and invent ways or employ alternative methods to solve problems. In a study carried out by Joy (2014), the study examined the effect of problem -based learning strategy on students' achievement in senior secondary schools chemistry in Enugu. The study employed quasi-experimental pre-test, post-test, non-equivalent control group design .In the study two hundred and one (201) total sample of senior secondary class two (SS II) Chemistry students from four single-sex schools (two male, two female) in Udi Educational zone Intact classes was selected. The Experimental groups were taught selected topics in Chemistry using problem-based learning method. Control groups were taught the same topics using expository .It was found out that students taught with problem-based learning strategy achieved better than those taught with expository method. Also, it was found out that male and female Chemistry students taught using problem-based strategy achieved equally.

Joy (2014) further opined that, the higher achievement could be as a result of the students' active participation in the teaching/learning process which characterizes the problem-based method. It demands from the learner acquisition of critical knowledge, problem solving proficiency, self-directed learning strategies and team participation skills. Also, problem-based learning reduces teachers' instruction and learners are seen as active participants in the classroom activities. High performance occurs in a learning situation where instruction must be concerned with the experiences and contexts that make students willing and able to learn (readiness). Learners' low achievement in Science in Ghana has been a concern to government, stakeholders, school principals and parents over the years as a result of poor teaching techniques, students' attitudes, lack of teaching and learning materials, teachers' pedagogical skills etc.

A study done by Ayyildiz and Tarhan (2018) on the effect of PBL in teaching of chemistry lessons, enthalpy changes in systems, showed that learners taught via problem based instruction performed better than their counter parts taught via traditional teaching methods and had fewer alternative conceptions, conceptual difficulties, and lack of knowledge than did the control group. Also Ferreira and Trudel (2012), conducted a study on the Impact of PBL on Student Attitudes toward Science, Problem-Solving Skills, and perception of learner's environment. The results from the study indicated a significant increase in student attitudes towards science, problem-solving skills and positive views of the learning environment. The use of PBL facilitated the development of a sense of community in the classroom. According to Cobern (1996), teachers should be sensitive to the culture of their students. Teachers need to be aware of the fact that science concepts are often quite abstract and foreign to students. Science concepts need to be presented to students in a manner that makes sense to students (Cobern, 1996).

The learning process in the Ghanaian science lessons now needs to be increasingly based on the capacity to find and access knowledge and to apply it in problem solving. Learning at the Senior High School in Ghana should be learning to learn, learning to transform information into new knowledge, and learning to translate new knowledge into applications. This become more useful than memorizing specific information. Also Tiwari, Lai, So, and Yuen (2006), conducted research on a comparison in effect between PBL and lecture learning on the critical thinking skill. The research used two classes, namely, a PBL class of forty students and a class of thirty-nine students learning with the method of lecturing. Measurements were done by using the California Critical Thinking Disposition Inventory (CCTDI). The result indicates overall improvement of the PBL class in the CCTDI (with p = .0048). On the whole, there is a significant difference in the class using PBL compared with the class using the lecture method. Chin and Chia (2004), emphasized the innovation in Singapore"s science curriculum in 1998. The Ministry of Education initiated *Thinking Schools, Learning Nation* which included revising all science content to include more ―inquiry oriented lessons" (p. 707), and ―collaborative project work" (p. 708) is part of inquiry oriented lessons (thus mirroring the concepts of PBL).

In (1910), John Dewey addressed the American Association for the Advancement of Science and spoke about how students were not ―flocking" to the study of science as was generally predicted based on technological advancements in the latter part of the 19th century. He said that perhaps science was taught too much as an accumulation of knowledge and less as a method of thinking. In looking at the importance of critical thinking as an essential 21st century skill, it is time that science education in Ghana look back to Dewey for guidance in developing a science education experience that can produce the outcomes, not the test scores, that the Ghana has been hoping to achieve since independence.

Sungur, Tekkaya, and Geban (2006) conducted a study with sixty- one (61) tenth graders from Turkey studying a unit on the human excretory system. Those students in the PBL treatment group earned significantly higher scores than the control group in regard to science achievement (M = 21.03, M = 17.75 respectively) and performance skills (M = 22.39, M = 1.49 respectively). In their study, the effect of problem-based learning on students' academic achievement and performance skills in a unit on the human excretory system was investigated. Sixty-one 10th grade students, from two full classes instructed by the same biology teacher, were involved in the study. Classes were randomly assigned as either the experimental or the control group and were pre- and post-tested to determine their academic achievement and performance skills before and after the treatment. The experimental group was taught with problem-based learning while the control group received traditionally-designed biology instruction. Results showed that although there was no pre-existing difference between two groups, students instructed with problem-based learning earned significantly higher scores than those instructed with traditionally-designed biology instruction-in terms of academic achievement and performance skills. Students in the experimental group appeared to be more proficient in the use and organization of relevant information, in constructing knowledge and moving toward better conclusions. Not only were they better able to organize and use relevant information, but they made stronger conclusions. PBL students believed that the cooperative approach of PBL coupled with the practical application of knowledge contributed to their learning. Tarhan and Acar (2007) study of PBL with an 11th-grade chemistry class showed that PBL treatment students achieved 33% higher than the control in cell content knowledge. They argued that PBL is highly effective in both the formation of knowledge and the improvement of social skills.

Chin and Chia (2004) found that students learned more when the content was related to real life issues with which students identified. Their 18-week study of a 9th- grade biology unit on food and nutrition differed from other PBL studies in that it focused on Question-Driven PBL (Q-DPBL). Q-DPBL argues that student questions drive learning and that student-generated problems via self-composed narratives increase interest and motivation. They discovered that students‟ self-generated questions and problems were inspired by their own experiences such as cultural beliefs and folklore, media, personal experiences, and previous learning. A study by Wong and Day (2009), focused on students aged 12 and 13. One teacher taught both the treatment and control groups two units: one of traditionally high student interest (i.e., reproduction) and one of low interest (i.e., density). They found that students learning via PBL achieved higher order learning goals, higher motivation through curiosity, and better retention in both units (42% positive change for control compared to 79% positive change for treatment in reproduction unit; 35% positive change for control compared to 162% positive change for treatment in density unit.) As evidenced by this study and the preceding secondary studies, PBL has had positive outcomes on students in secondary science.

While public concern over science education in Ghana continues to make headlines, it is not a new issue. In fact, for nearly 50years, Ghana has been critiquing and scrutinizing science education, creating policy, developing and implementing programs designed to encourage students to pursue the fields of science, technology, engineering, and mathematics and yet the number of students responding to this challenge continues to be low. The way to arouse the interest of learners in Science is the use of innovative methods like PBL, which turns the student from passive information recipient to active, free self-learner and problem solver, slides the emphasis of educational programs from teaching to learning. By means of problem-based learning, some attitudes of students in relation to such areas as problem-solving, thinking, group works, communication, information acquisition and information sharing with others are affected positively. Problem based learning is an efficient learning method which helps in improving academic achievement , provides long-term information keeping , develops problem solving skills and fosters critical thinking. The basis of the problem-based learning is mainly comprised of ‗Problem, Solution, Practice, Research, Questioning, Realism, Originality and Integration." The global emerging trends in the pedagogical practices are approaches where learners take the responsibility of their learning and the opportunity to participate adequately in learning process as the teacher become a guide. In any classroom setting, learning occurs majorly through teaching or instruction as teaching and learning are just like the two sides of a coin.

In the process of learning, knowledge, skills, or attitudes are imparted to the learners by the teachers. The process of science learning can be expository, and unfruitful when facts and knowledge are acquire through memorization without meaningful understanding of the underlying principles. Learning can also be an active process, rather than a collection of factual or procedural knowledge. This kind of learning process involves the learners' active participation and interactions (such as doing, discovering, discussion and problem solving) with peers and materials to be learnt (Cole 1986, Eggen and Kauchak, 1993).

2.16 Chapter Summary

It is need of the day that Senior High Students should be prepared in a way that they possess certain basic skills to work in diversified circumstances. A number of educational philosophies provide modalities essential for the development of human being. Pragmatism and progressivism view human learning as a process of learning by experiencing the real world (Richardson, 2003). Experiencing therefore have to do with one‘s ability to solve problem which he or she faces in everyday life. Conventional methods of teaching chemistry has been practiced for a long period in Senior High schools where teacher dominates the learning process through lectures and note taking. Students had to connect what they learn from the superficial abstract contents delivered by teachers in class with the real world life problems in the society.

The problem addressed by this study was that senior High School students‘ who learn elective chemistry in Nkrankwanta Senior High Technical School have difficulties in understanding most concepts and topics in chemistry over the years. This was noticed by the researcher through his personal interaction with the students as a teacher in the school and close examination of the students‘ performance in solving chemistry problems. Instructional and learning gaps in teaching and learning of chemistry using PBL in some selected topics in chemistry have been identified and justification for the study established in this literature. The literature in this chapter has posited that a problem-based learning approach to teaching chemistry is a learner-centered approach. This is supported by the theoretical approach constructivism which has two belief systems (radical and social constructivism). In the constructivist classroom, the teacher‘s role is to organize situations which will give way to the learners to hypothesise, predict, manipulate objects, pose questions, research, investigate and invent meanings relevant to what they are learning(Kibos, Wachanga, & Changeiywo, 2015).

The locus of learning is to condition students‘ to respond to stimuli from the external environment, so that learners learn to adapt to any environment, this is supported by the behaviorist theoretical approach which in turn help to produce learners that can change their behavior in desirable ways. The study also considered learners to be self-actualized, autonomous and independent in everything they have learned where the teacher facilitates learner improvement and development as a whole person. This paradigm shift was supported by the humanist learning theory. The current study has addressed gaps in the areas of PBL, and has argued that problem-based learning approach to teaching chemistry is a learner-centered approach that help learners construct their own knowledge of learning by interacting cooperatively and collaboratively in small or large social groups through engaging actively in problem based tasks/activities. It is very important that senior high school students develop critical and analytical abilities to deal with the complexities in solving chemistry problems. Consonant to this level of importance, PBL is seen as a vehicle for helping students' acquire the necessary level of cognitive achievements in solving chemistry problems. Most of the reviewed literatures in this study employed quasi experimental design which successfully helped learners' acquire necessary skills, such as critical thinking, and problem solving abilities, searching and self-directed learning. The sample of second year students in Senior High school and utilization of nonequivalent pre-test and posttest quasi experimental design used in this study helped fill missing methodological gap and several relationships were examined that filled construct related holes.

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter deals with methodology used in the study. In this chapter, the research design, the description of the population, the target population, sampling techniques and sample size, construction of research instruments, pilot study conducted, data collection procedure, data analysis procedure, intervention for experimental group and ethical consideration for the study are also discussed.

3.1 Research Design

Research design is a formal plan of action for a research project. A research design identifies the specific methods and procedures applied in a research study in providing a solution to a research problem. Research design, according to Worgu (1991), is a plan or blue print which specifies how data relating to a given problem should be collected and analyzed. Research design provides the glue that holds the research project together (Trochim, 2006). This study employed a quasi-experimental design, specifically the non-equivalent control group design. Quasi-experiment is an empirical study used to estimate the causal impact of an intervention on its target population (Vanderstoep & Johnson, 2008). A quasi-experimental design is a type of design that does not provide for full control of extraneous variables, primarily because of the lack of random assignment of subjects to groups (Ali, 2006).

The researcher used quasi- experimental design since the study was conducted in a classroom setting and there was no random assignment of participants to group. Also the researcher used quasi experimental design because he wanted to establish a causal relationship between the control and the experimental group. The design involved the use of methods and procedures that made observations in the study structured similar to experiments, but the conditions and experiences of students lack some control because the study lacks random assignment and includes a pre-existing factor (Wiersma, 1985). The ultimate goal of a good research design is to provide a credible answer to the research questions (McMillan & Schumacher, 2010). Two groups were selected by simple random and convenience sampling technique, namely experimental and control groups. Both Pre-treatment and Post-treatmet were conducted using Chemistry Achievement Test (CAT). The experimental group received the treatment (*a problem-based learning approach)* whereas the control group did not. The control group was used to establish a baseline for reading achievement in this study.

R_E	O1	X	O3
R_C	O2	Ⓧ	O4

Figure 3: Nonequivalent (Pre-Test and Post-Test) Quasi-Experimental Design

KEY

R_E = treatment group

R_C = control group

X = treatment (a problem-based learning approach)

Ⓧ = no treatment

O1 = O2 = pre-test

O3 = O4 = post-test

In addition, qualitative data was also collected to provide a deeper understanding and multiple realities of the phenomenon under study. Using both simple random and purposive sampling techniques on students‘ level of understanding of the selected topics used in the research, based on concepts application of pre-test and post-test scores, Questionnaires for learners, was utilized to gather multiple perspectives as they emerged (Anzul, Ely, Freidman, Garner, & McCormack-Steinmetz, 2003).

3.2 Population

Kanne (2004) defined population as the entire group of individuals from which a sample may be selected for statistical measurement. There are two types of population in any study, the target population, and the population from which the researcher can realistically select subjects, which is known as the accessible population or available. According Amedahe (2001) the target population of a study is the aggregate of cases about which the researcher would like to make generalisations and it is the units from which the information is required and actually studied. In addition, Amedahe (2001) defined the accessible population as the designated criteria that are accessible to the researcher as a pool of subjects for a study.

According to Amedahe (2001), researchers usually sample from an accessible population and hope to generalize to a target population. The target population for this study was all second year Senior High School students‘ in the Bono Region that learns elective chemistry as a subject. The accessible population was all second year students who offer General science and Agricultural science as course at Nkrankwanta Senior High Technical School in Dormaa West Constituency of Bono Region. There is only one Senior High School in the Dormaa West Constituency, Nkrankwanta in the Bono Region. Bono Region was selected using convenience sampling technique. The average age of the students was sixteen years and most of them comes from nearby towns in the constituency. Nkrankwata Senior High School offers six major courses namely; General Science, Home Economics, General Art, Business , Technical and Agricultural science. The school is a mixed school with a population of one thousand four hundred students as at 2020/2021 academic year.

About 40% of the students are day students whereas 60% of them are in the boarding house, with a teacher population of 60 of which only one is a chemistry teacher. Only students who offer General Science and Agricultural Science as a course learn chemistry as a subject. The total population for the study consisted of 250 second year senior high school students‘ who learn chemistry as an elective subject in Nkrankwanta Senior High Technical School. As the students‘ population was very large to handle and also there was inadequate resources, it was necessary to work with a sample of the population.

3.3 Sample

The sample population was (1) Senior High School in Dormaa West Constituency, Nkrankwanta, in the Bono Region. The sample for this study was made up of two SHS Form 2 class from the selected School that is, Nkrankwanta Senior High Technical School. The intact SHS 2 classes were made up of students who offered Chemistry as an elective subject. Second year SHS students were used in the study because the selected chemistry topics used in the study that is; Acids, Bases and Redox Reaction was part of the SHS 2 Elective Chemistry syllabus. Also, SHS 2 students in the selected school were yet to be taught _the selected topics‘ in elective chemistry as at the time the study commenced. Also the researcher selected the second year science students who learn chemistry as a subject, because, they had chemistry background from first year and have covered most chemistry topics in the first year chemistry syllabus.

These second year students have one more year ahead of them to complete the SHS, there was therefore no pressure of WASSCE examination for them to write and therefore they will had more time to adjust to any change in approach to teaching them chemistry. Participants in this study were of similar educational background as they had all passed the Basic Education Certificate Examination (BECE) at the Junior High School (JHS) level as well as their year one Elective Chemistry examination. The total sample size was Eighty-Five (85) elective chemistry students. This comprised of Form Two science one and Form Two Agricultural science one students. They were categorized as Control and Experimental groups. The Control group was made up of forty-five (45) students and the Experimental group forty (40) students. The Form Two Science One class was assigned the control group and was not subjected to any treatment, whiles Form Two Agricultural Science One class was also assigned the experimental group. There is a belief by the science teachers at Nkrankwanta Senior High School that, students in the Science classes perform better in the science related subjects than the students in Agricultural Science classes. This therefore was the reason why the researcher assigned the Form Two Agricultural science One students as the experimental group and subjected them to treatment using the PBL. The number of students in both study groups is represented in table 3.1

Table 1: Number of Students in both Study Groups

	Male	**Female**	**Total**
Experimental group	24	16	40
Control group	26	19	45
Total	**50**	**35**	**85**

Evidently from Table 1, 40 students were in the Experimental Group and 45 were in the Control Group. Moreover, 50 male and 35 female students took part in the study and there were 24 males and 16 females in the experimental group, while 26 males and 19 females were in the control group.

3.4 Sampling Procedure

Sampling is a procedure of using a small number of items or part of a whole population to make conclusions about the population. The quality of a piece of research stands or falls by the appropriateness of its methodology and instrumentation and by the suitability of the sampling strategy that has been adopted. Sampling enables a researcher to estimate some unknown characteristics of the population and make population (Zikmund, Babin, Carr, & Griffin, 2010). In a sampling procedure, two major sampling techniques comes into mind. The first is random sampling technique which is based on the theory of probability where each population element is given a known non-zero chance of selection ensuring that the sample will be representative of the population (Wickens & Keppel, 2004). The second is non-probability sampling, also called nonrandom sampling, is the process of selecting a sample using a technique that does not permit the researcher to specify the probability, or chance, that each member of a population has a chance of being selected for the sample.

The study employed both random and non-random sampling techniques. That is, convenience and purposive sampling as a non-random sampling technique and simple random as a random sampling technique was used for the study. Simple random sampling is the process of selecting a sample in such a way that all individuals in the defined population have an equal and independent chance of selection for the sample. The selection of the sample is completely out of the researcher‘s control; instead, a random, or chance, procedure selects the sample. Convenience sampling, also referred to as accidental sampling or haphazard sampling, is the process of including whoever happens to be available at the time. In convenience sampling, members of the target population that meet certain practical procedure such as easy accessibility, geographical proximity, availability of a given time or the willingness of subjects to participate are included for the purpose of the study (Nechval & Nechval, 2016).

Purposive sampling, also referred to as judgment sampling, is the process of selecting a sample that is believed to be representative of a given population. In purposive sampling one selects the sample using his experience and knowledge of the group to be sampled and does not need any underlying theories. Convenience sampling technique was used to select the Region and also the Senior High School because of proximity, easy access and special characteristics of the selected Senior High School. The researcher then used purposive sampling techniques to select the two classes for the study by categorising the classes into control and experimental groups.

The researcher finally used purposive sampling to select respondents for the questionnaire after the post-test. In ensuring that each individual in the population would have equal chance of been selected for the study, the sample units in the population was selected by a random process, using a random number table also called table of random digits. The Form Two (2) Science One (1) intact class that was assigned the control group consisted of sixty-five (65) students. The researcher assigned the students' with numbers 01 to 65 with their respective names. With the use of excel software the researcher generated list of random numbers by launching excel on the computer and typing in the cell = RANDBETWEEN (bottom, top).

The number of digits chosen for bottom and top would be generated with such digits. When drag would result a list of random numbers in rows and columns. The row was chosen with two digits as a start point, when the selected two-digit numbers coincide with any of the student's numbers, that student would be selected for the study. The excel random number generator technique was used to select forty (40) students for the experimental group. The other Form Two (2) intact class consisted of seventy three (73) students. With the use of excel random number generator technique, forty (45) students were also selected using the same procedure for the experimental group and was assigned the control group.

The two Form Two (2) classes were labelled Form 2AG1 for Experimental group and Form 2SCI1 for the Control group. In assigning the two classes as experimental and control group, the researcher used purposive sampling technique based on the reason that there is an observed trend by the science teachers at Nkrankwanta Senior High School that, students in the Science classes perform better in the science related subjects than the students in Agricultural Science classes. This therefore informed the researcher to assign the Form 2AG1 students as the experimental group and subjected them to treatment using PBL teaching approach.

3.5 Research Instrument

Research instruments selected for the study were:

i. Researcher made treatment and post-treatment Chemistry Achievement Test (CAT)
ii. Questionnaire

3.6 Chemistry Achievement Test (CAT)

The Chemistry achievement test was made up of pre-test and post-test. Each group (control and experimental) was given a pre-test (Appendix A) before the treatment and a post-test after the treatment (Appendix B). The pre-test consisted of by 20 multiple-choice and one essay typed item that was developed by the researcher to identify students‘ prerequisite knowledge for learning acids, bases and redox reaction. Both tests assessed students _content knowledge and understanding on the selected topics in chemistry. The post-test also consisted of 20 multiple choice and one essay type item to measure students‘ academic achievement and performance skills respectively (see Appendix B). Items in the test were related to the selected chemistry topics.

Essay type item was prepared in accordance with a problem-based learning approach aimed at measuring students‘ performance skills such as ability to use relevant information in addressing the problem, articulate uncertainties, organise concepts, and interpret information. 40 minutes was the time allotted for students for both tests. Each test consisted of two sections, 1 and 2 with section 1 made up of 20 compulsory multiple choice whiles section 2 had one compulsory essay type question. The pre- and post-tests were marked out of 30 marks each, 20 marks for the multiple-choice questions in section 1 and 10 marks for the essay type item in section 2. Each correct response in section 1 attracted a maximum of one mark whereas a question in section 2 attracted 10 marks see appendices (C and D).

The multiple-choice items consisted of one correct answer and three distracters that is alternative (A-D) which reflect students‘ alternative conceptions. The content of the test was validated by three experts in chemistry education and four senior high school chemistry teachers. The order or sequence of numbers of questions, and numerical figures in the questions were different for the two tests. To ensure security, validity and reliability of test items, the questions for the pre-test and post-test were set, typed, and copies run by the researcher. For the multiple-choice questions in both pre-test and post-test, the researcher adopted the scoring scheme by Haidar and Abraham (1991) , which states that, firstly answers of the multiple-choice items were classified as correct (1 points), incorrect and no answers (0 points).

3.7 Questionnaire

A five point Likert scale questionnaire was developed by the researcher, named problem-based learning attitude questionnaire (PBLAQ). The PBLAQ was used to assess students' attitude towards learning of chemistry using PBL. The questionnaire was mainly 30- item closed-ended questionnaires and was administered to students in the experimental group (Appendices E, F, and G). The items consisted of both positive and negative statements to avoid students" answers being skewed toward the positive response options to avoid response bias. Negatively-worded items are added to the scale to act as ―cognitive speed bumps that require respondents to engage in more controlled, as opposed to automatic, cognitive processing" (Chen, Rendina-Gobioff, & Dedrick, 2007).

Using negatively worded questions to minimize response bias is based on the crucial assumption that the items worded in the opposite ways are measuring the same concept that the positively worded items are measuring (Chen et al., 2007). The items were rated on 5– point Likert type interval scale ranging from Strongly Agree (SA) to strongly disagree (SD). (1= strongly disagree and 5= strongly agree). Items which indicate positive attitude were graded on points ranging from strongly agree =5; Agree = 4; Neutral'' = 3; Disagree = 2 and strongly disagree'' =1. Negative attitude were oppositely graded that is: ‗strongly agree ‗=1; Agree =2; ‗Neutral = 3; " Disagree =4 and ‗strongly disagree''=5. The items in the questionnaire were divided into the following three sections:

Section 1: Questionnaire on Students' Attitude towards Problem-Based Learning

Section 2: Students' Self- Learning and Satisfaction Level in the Selected Topics in Chemistry Using Problem-Based Learning

Section 3: Experimental Group General Views about Problem-Based Learning Questionnaire.

3.8 Validity of the Instrument

Unreliable instruments can introduce serious errors into research. Validity of an instrument is the extent to which the items in an instrument measure what they are set to measure. Validity refers to the degree to which a test measures what it is supposed to measure and, consequently, permits appropriate interpretation of scores. An instrument is considered valid when there is confidence that it measures what it is intended to measure in a given situation (Punch, 2013).

The content validity of test items were determined by ensuring that, questions for both the pre-test and the post-test were set from the selected topics used for the research and were within the scope of the Ghana Education Service approved chemistry syllabus for Senior High Schools to ensure a fair and representative sample of questions. To ensure that participants' scores from the pre- test and post-test were valid, meaningful and to ensure good conclusions from the sample studied and the research population, both test instruments were presented to four experts in chemistry education and four senior high school chemistry teachers for scrutiny. Also the draft questionnaires were shown to the researcher's supervisor and some experienced chemistry educators and chemistry teachers in some Senior High Schools for scrutiny. In ensuring construct validity, the study used test and questionnaire (triangulation), and piloting, in addition as instruments for collecting data from its respondent to ensure triangulation of data.

3.9 Reliability of the Instrument

Reliability refers to the consistency of scores or answers from one administration of an instrument to another and from one set of items to another. This means that scores from an instrument should be stable and consistent and should be nearly the same when researchers administer the instrument multiple times at different times. A research instruments should produce scores that are stable and consistent and their test items should be devoid of any ambiguities (Creswell, 2002). The more reliable a test is, the more confidence we can have that the scores obtained from the test are essentially the same scores that would be obtained if the test were re administered to the same test takers at another time or by a different person. The study used test-retest reliability method to assess the test items for both the pre-test and the post-test. The test items were administered to students who learn elective chemistry as a subject in Mansen Senior high School at Wamfie in the Dormaa East constituency for three times within three weeks after the piloting stage.

The results of the 1st, 2nd 3rd test scores were almost the same, the difference was not significant which showed that the test items were reliable and standard. Also the researcher used the Cronbach‘s Alpha coefficient as a measure of the internal consistency for the questionnaire, it was found to be 0.80. According to Mugenda and Mugenda (2003), the coefficient is high when its absolute value is greater than or equal to 0.7: otherwise it is low. A high coefficient implies high correlation between variables indicating a high consistency among the variables.

3.10 Pilot Testing of the Instruments

A pilot study is a feasibility studies that are mini-version of a full-scale study or a trial run done in preparation for the major study. Pilot study involves trying out all research techniques and methods, which the researcher have in mind to see how well they will work in practice

According ,Blaxter, Hughes, and Tight (1997), (Pg. 135) ―You may think that you know well enough what you are doing, but the value of pilot research cannot be overestimated. Things never work quite the way you envisage, even if you have done them many times before, and they have a nasty habit of turning out very differently than you expected". It is thus very clear to the researcher, that the pilot study in the current research was essential to prevent the waste of time, energy and money. The general goal of a pilot study is to provide information, which can contribute to the success of the research project as a whole. In the study the goal of the pilot study consists of two parts. The first was to find as many as possible practical arrangements that might have a negative influence on the success of the research procedure. The other included sorting out all practicalities related to measurement instruments as well as the applicability of these instruments to the potential outcomes of the study.

According to Welman and Kruger (1999), many novice researchers are disillusioned when they find out that the guidelines for research are only valid in an ideal environment, and not in the practical research environment where they conduct their research study. This might be the main reason why a pilot study is needed. It is needed to detect possible flaws in measurement procedures (including instructions, time limits, and etcetera) and in the operationalisation of independent variables. This value of the pilot study was very applicable in the current research study. Also One of the advantages of conducting a pilot study is that it might give advance warning about where the main research project could fail, where research protocols may not be followed, or whether proposed methods or instruments are inappropriate or too complicated(Van Teijlingen & Hundley, 2001).

The CAT for both pre-test and post-test and PBLAQ instruments were pilot tested in a school different from the study school but whose sample shared similar characteristics (age, class level and exposure to the same curriculum) with the study school. The results of the students were used for item analysis. Both discrimination index and item difficulty were calculated purposely for evaluating the quality of the items and of the test as a whole and revising and improving both items and the test as a whole as much as possible, the chemistry achievement test for both the pre-test and the post-test were pilot-tested using twenty (20) SHS elective chemistry students in Dormaa Senior High School in the Bono Region. The pilot test consisted of ten (10) multiple choice typed questions with two essay typed questions where the researcher considered the selected topics for the study. From the feedback obtained after piloting, the study instruments were refined. The multiple choice questions for the pre-treatment and post-treatment test questions as well as the essay typed questions were reduced from 30 to 20 and 2 to 1 respectively.

Also questions and items in the questionnaire that proved difficult for student to respond to, were reframed to make it more understandable. The pilot study helped the researcher to draw a base-line for the validity and reliability of the instruments and the procedures to be followed for the study.

3.11 Data Collection Procedure

The researcher first sought research permit from the selected senior high school used for the study. After a thorough discussion of the study and its benefits to the headmaster and the Head of Department of science for the selected senior high school, the research study began. The study began with the administration of the pre-test to students in the control and experimental group. The pre-test administration took place with the help of the chemistry teacher in the selected senior high school for the study. The pre-test consisted of twenty multiple-choice and one theory to be answered by both groups (Control and Experimental groups) marked out of 30 (See Appendix A). The completed scripts were marked by the researcher using a marking scheme (scoring rubric) prepared by the researcher (Appendix C).

The researcher used six weeks for the experimental process, during which the researcher handled the experimental group and the chemistry teacher in the researcher‗s selected school handled the control group. Before the experimental process, the chemistry teacher that handled the control group was taken through an orientation process by the researcher on how to handle the control group by using conventional method during lesson delivery. Also to ensure the practicability of this, the researcher vetted the lesson plan prepared by the chemistry teacher that handled the control group and was always directed by the researcher on the best way to apply conventional method for teaching the selected topics.

The researcher did not handle the control group because he wanted to prevent susceptibility by the students in the control and the experimental group and also wanted to ensure independence on the students in both the control and the experimental groups. Also since the study took place in an environment where the researcher was present, he monitored the teaching method adopted by the chemistry teacher in the control group and made sure he always used conventional method which involved the use of talk and chalk method on board style, in which the teacher dominate the teaching and learning encounter. The main treatment was teaching of acids and bases and redox reactions to experimental group using the lesson package problem-based learning approach developed by the researcher. All the necessary information about the concept were given and explained to the students. The students in the experimental group were guided to construct new ideas and concept that is their own knowledge during and after the lesson with the teacher acting as a facilitator, by asking students probing questions that will enable them be on the track, monitoring the process, and making resources available.

The teaching of both experimental and control group was done during the normal school‘s chemistry periods. The six weeks experimental teaching process ended with post-treatment Appendix (B) consisting of twenty multiple choice questions and one standard theory question different from the pre-test was given to both groups to complete in order to help the researcher to answer the null hypothesis one and two formulated from research question one and two. The completed scripts were marked by the researcher using a marking scheme (scoring rubric) prepared by the researcher. Marking schemes for Pre-test (See Appendix C) and marking scheme for Post-test (See Appendix D).

A questionnaire was administered. A five point Likert scale questionnaire developed by the researcher, named problem-based learning attitude questionnaires (PBLAQ) was administered to the students in the experimental group. The questionnaire was mainly 30- item closed-ended questionnaire and was administered to the students‘ in the experimental group (Appendices E, F and G). The PBLAQ was used to assess students‘ attitude towards the learning of chemistry using PBL.

3.12 Data Analysis Procedure

Data Analysis is the process of systematically applying statistical and/or logical techniques to describe and illustrate, condense and recap, and evaluate data. The purpose of analysing data is to obtain usable and useful information. The analysis, irrespective of whether the data is qualitative or quantitative, may describe and summarise the data, identify relationships between variables, compare variable, identify the difference between variables and forecast outcomes. The data obtained from the learners through the pre-intervention and post-intervention test and questionnaires were organised and summarised to obtain a general sense of information and to reflect on its overall meaning from the conducted research.

The description and themes obtained were represented in quantitative terms and in qualitative narratives (e.g., frequency tables showing means, standard deviations, test statistics, and graphs). The researcher then made interpretations of the collected data based on literature findings and theories. Microsoft Excel and the SPSS IBM 20 software were used to assist and enhance the analysis. The researcher used quantitative approach of data analysis for research question one (1) where he sought to determine the extent of student‘s performance in chemistry when exposed to Problem based learning approach.

With this, the researcher conducted a pre-test and post-test with the experimental and control groups. The researcher adopted descriptive analysis of quantitative approach which sought to organise and describe the data by investigating how the scores on different constructs are related to each other. Furthermore , the pre-test and post-test scores were further analysed using inferential approach for quantitative data analysis where the researcher used a t- test statistics to determine if the treatment had effects on the groups. In this method of analysis, data obtained from participants in both experimental and control groups were analyzed statistically using independent and dependent sample *t*- test. The difference between the mean scores of both groups on the pre-test post - test scores were tested at a 0.05 significant level.

The independent and dependent sample *t*-test was used to investigate whether any differences existed between experimental and control groups' mean scores on the CAT. This was done to answer the research question one (1) and either to reject or fail to reject the null hypotheses ―*There* is no statistically significant difference that a problem-based learning approach made on the mean scores of students' performance in chemistry". Research question two (2) which sought to find the differential impact of the problem-based learning approach on male and female students' cognitive achievement in the selected topics in chemistry also adopted descriptive and inferential statistics. The descriptive statistics which employed mean helped in determining the relationship between the male and female student' in the experimental group scores in the pre-test and posttest. Pre-test and posttest scores were further analysed using inferential statistics for quantitative data where the researcher used t-test statistics to determine if the treatment had any differential impact on the performance of male and female students exposed to problem-based learning approach.

The difference between the mean scores of both groups on the pre-test and posttest scores were tested at a 0.05 significant level. The independent and dependent sample *t*-test was used to investigate whether any differences existed between experimental group male and female students' mean scores on the CAT. This was done to answer the research question two (2) and either to reject or fail to reject ―the null hypothesis two (2) which states that there is no statistically significant difference between the mean chemistry achievement pretest and posttest scores of male and female students in the experimental group‘‘. Research question three (3) sought to identify some attitudes students posed when exposed to problem-based learning approach. With this, the researcher used a researcher made questionnaire and collected data on students‘ attitude in the experimental group when they were exposed to problem-based learning approach while research question four (4) sought to identify some difficulties the students in the control and experimental group had in solving chemistry problems.

The researcher used the selected topics that is acids, bases and redox reactions as a speed bump in identifying some difficulties students in the control and experimental group had in solving chemistry problems. The study conducted a descriptive analysis on both research question three (3) and four (4) which employed the use of percentages. The main purpose was to provide a brief summary of the samples and the measures done on the research study.

3.13 Intervention for Experimental Group

Problem-based learning (PBL) is an instructional strategy in which students actively resolve complex problems in realistic situations. The steps below were followed for the PBL approach during the intervention.

Steps in Problem-Based Learning Approach

1. Selection of problem.
2. Presentation of problem.
3. Collection of facts.
4. Drawing an outlines.
5. To reach a satisfactory conclusion.
6. Evaluation.
7. Writing report.

In PBL the problems must address concepts and principles relevant to the content domain. The researcher devised PBL activities that incorporated multidisciplinary approaches. The researcher provided and coordinated needed resources such as additional content, instructional support. In addition, students were allowed to ask probing questions on the content of the presented problem which helped to reveal further information, and synthesize critical factors throughout the problem-based learning process. As a facilitator, the researcher gave students control over how they learn the selected concepts in acids, bases and redox reactions. The pre-test questions gave a fore idea of the various difficulties students experienced in solving problems in acids, bases and redox reaction. The intervention period took six weeks of two hours lesson every week. In the first three weeks students were taken through basic definitions of acids and bases, pH and pOH of solutions as well as finding dissociation constants of acids and bases. The researcher devised PBL activities that incorporated multidisciplinary approaches. The researcher allowed students develop alternative hypotheses to resolve the problem and discuss and negotiate their conjectures in a group. For the next three weeks the students were taken through redox reactions lessons. In the first week lesson students were given activities in redox reaction to distinguish oxidation reactions from reduction reactions. The researcher helped the students to develop clearly stated solutions that fit the problem and its inherent conditions, based upon information and reasoning to support their arguments. The students were further taken through balancing of redox reaction in the last two weeks. During the teaching and learning process the researcher acted primarily as cognitive coach by facilitating learning and modeling higher order thinking and Meta cognitive skills. Problems selected by the researcher were not investigated by students solely for problem solving experiences but as a means of understanding the subject area. The researcher provided support and structure in the direction of the students in the experimental group learning. In the intervention process an ill-structured problem that has no obvious solution was selected for the students. The researcher assisted the students to access, evaluate, and utilize data from a variety of available sources to support or refute their hypotheses. With the help of the researcher, they were allowed to alter, develop, or synthesize hypotheses in light of new information. Finally the researcher helped the students to develop clearly stated solutions that fit the problem and its inherent conditions, based upon information and reasoning to support their arguments. Solutions to arduous problems was presented be in the form of essays, presentations, and projects.

3.14 Ethical Consideration

Ethical considerations including the dignity and wellbeing of students were protected at all times. The research data remained confidential throughout the study and confidentiality of information, names, and sources. Also special emphasis was laid on confidentiality or anonymity of questionnaires in case of sensitive or gazette data. The study was carried out with available funds and within the available timeframe without complacency.

3.15 Chapter Summary

This chapter has introduced the research design, study population; the study location, sampling techniques, sampling size, research instruments and pilot study used have been described. How the data was obtained from students' in Nkrankwanta Senior High School students' through chemistry achievement test and questionnaires were organised and summarized to obtain a general sense of information and overall meaning have been dealt with. Appropriate methods were used to ensure validity and reliability of data. Lastly the chapter considered data collection procedure, data analysis procedure, intervention for experimental group and the ethical considerations.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This chapter looks at analysis, interpretation and discussion of findings of the data collected from the study. Both descriptive and inferential analysis technique was employed in analysing the collected data. The order of presentation and discussion of the results obtained in this study were discussed in accordance with the research questions formulated for the study.

4.1 Biographic Data of Respondents

Although the biographic data were not pivotal to the study, they helped the researcher to present information on the characteristics and entry behaviour of the participants used for the research and also the interpretations of the findings. The biographic data considered in this study were: gender, age, class and class size. These findings are presented in figure 4

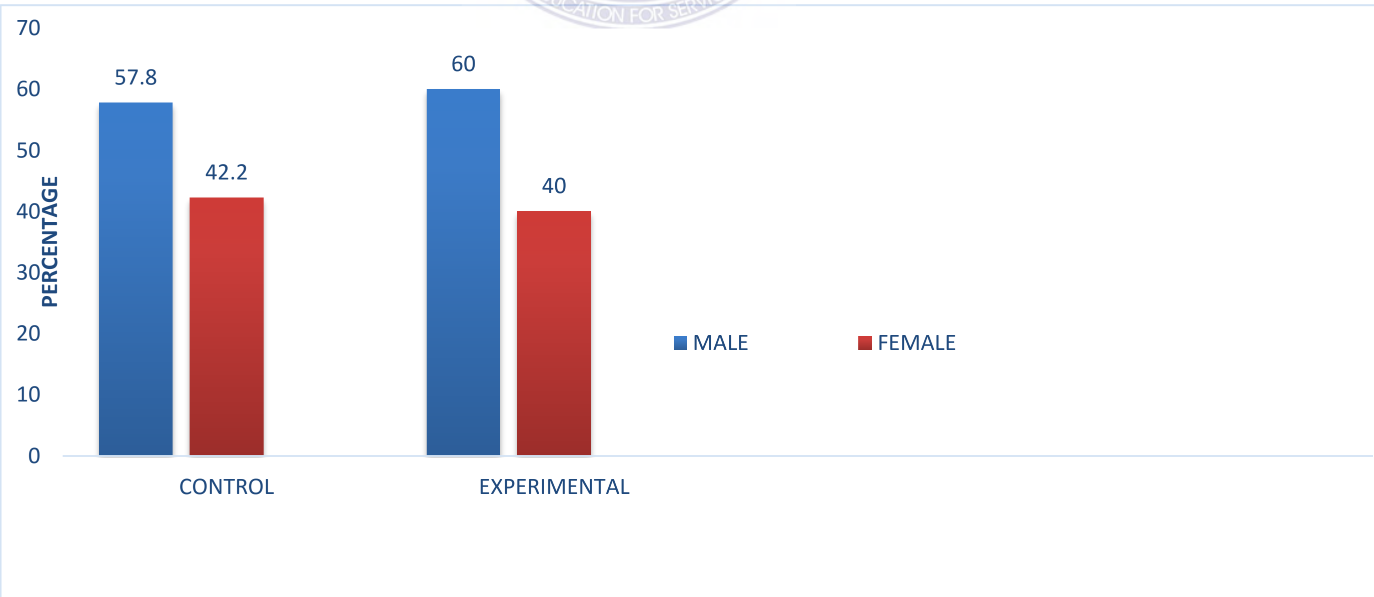

Figure 4: Respondents by Gender

The control group was made up of 45 participants which consisted of 26 males and 19 females representing (57.8%) and (42.2 %) respectively. The experimental group also was made up of forty 40 students which consisted 24 males and 16 females representing (60%) and (40%) respectively.

4.1.2 Class Size

Large class size can be a confounding variable to the practicing or implementation of a problem-based learning approach in the science classroom as the science teacher does not get the opportunity to consider the learning need of each of the learners. Manageable class size makes teaching and learning easier for the science teacher, taking into consideration the learning needs of every learner.

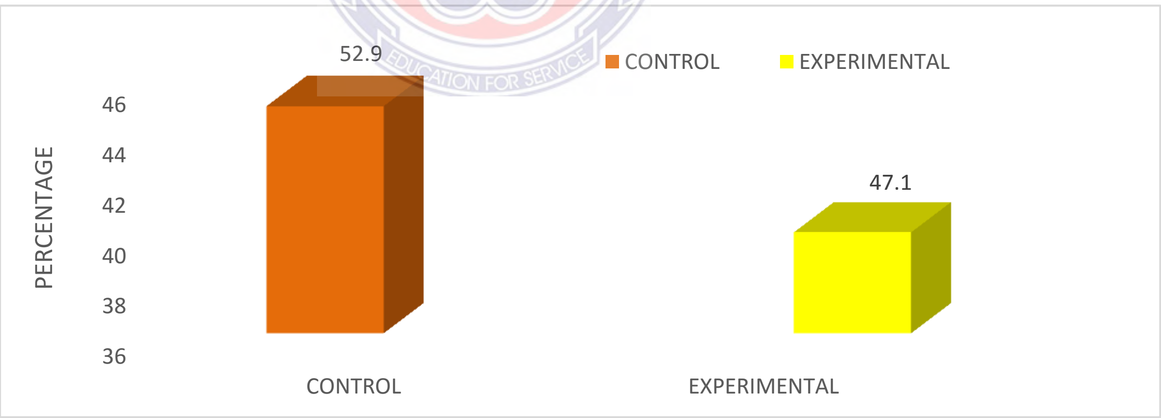

Figure 5: Respondents on Class Size

From Fig 5, 45 students representing 52.9 % of the total students involved in the study were assigned the control group. Also 40 students representing 47.1% of the total students involved in the study were assigned the experimental group. The above statistics give a clear evidence that a smaller percentage of the students was assigned the experimental group so that the researcher can implement the problem-based learning approach by considering the learning needs of all the learners.

4.2 Research Question One

What will be the extent of student‘s achievement in chemistry when exposed to Problem based learning approach?

4.3 Descriptive Analysis on Pre-Test Scores

This research question sought to find out the achievements of students who were exposed to the problem-based learning approach. To draw a baseline for the achievement of students exposed to the experimental treatment using problem-based learning approach and students exposed to conventional method in the control group, a pre- treatment test was first conducted to determine the prior knowledge of the students in acids- bases and redox reactions. The pre-test was scored out of a total of thirty marks in both the experimental and control groups. The pre-test consisted of twenty (20) multiple choice questions and one theory question. The pass mark that determined whether a student failed or passed the test was fifteen (15) marks. A student whose total score was below fifteen (15) failed the test and those who scores were exactly fifteen or above passed the test.

The inferential statistics on the students pretest is found in Table 2

Table 2: Independent Samples T-test of Pre-test scores of Chemistry Achievement Test (CAT)

Group	N	Df	Mean	SD	t- Value	P- Value
Control	45		21.29	3.709		
		83			11.920	1.143
Experimental	40		12.62	2.880		

Source: Field Data, 2021

It is evident from Table 2 that, the computed p-value 1.143 was greater than 0.05 indicating that there was a statistically no significant difference between the pre-treatment scores of the control and the experimental group. This mean that, the two groups were homogenous in solving chemistry problems. Therefore, the belief by the science teachers at Nkrankwanta Senior High School Technical that the student in the science classes who learn chemistry, Biology, Physics and Elective Mathematics as their elective subjects perform better than the science students in the Agricultural Science classes does not hold. The fact that there was no significant difference between the two groups gave an indication that the *Chemistry Achievement Test* conducted for the experimental and control group before treatment was the same and therefore the cognitive achievement of the participants in solving chemistry problems was the same. In order to improve the cognitive achievement of the group who had low mean indicating low performance in solving chemistry problems, the researcher subjected the experimental group to a treatment called problem-based learning approach to determine if their cognitive achievement will be enhanced than the control group.

4.4 Descriptive Analysis on Post-Test Scores

The post-test was administered after the participants in the experimental and control groups were introduced to the pre-test. Before administering the post-test, the control group were introduced to the conventional teaching method while the experimental group were also introduced to a treatment package, using problem-based learning approach in teaching acid, base and redox reactions. The intervention took six weeks after which the post- test was administered to the participants in the control and experimental groups based on the selected topics. In ensuring content and test validity the researcher ensured similarity for the questions in the pre-test and post-test. The similarity of the questions in the pre-test and post-test questions helped the researcher to assess the effectiveness of problem-based learning approach on the experimental group as compared to the control group who were taken through the normal conventional teaching approach.

A score of mark of fifteen and above indicated a pass mark whiles a score mark below fifteen indicated that the student has fail the test. After the post-test the researcher analysed the scripts of all the students in the experimental group one after the other to measure the impact of the problem-based learning on the individual cognitive achievement on the selected topics in chemistry. After compiling the results of the participants in the control and experimental groups, their results were analysed statistically with the aid of SPSS using independent t-test and dependent t-test for the pre-test and post- test of the students in the control and experimental group to find out if there was any statistical significant difference between the achievements of the control and experimental groups. The dependent t-test of the students pre-test and post-test is represented in Table 3.

Table 3: Dependent T- test of Pre-test and Post-test Scores of the Experimental Group Chemistry Achievement Test (CAT)

Group		N	DF	Mean	SD	t- value	P-value
	Pre –Test			12.62	2.880		
Experimental		40	39			-14.997	8.787E-18
	Post –Test			22.50	3.464		

Source: Field Data, 2021

From Table 3 above, the t-test results for the difference of means in the Experimental group pre-treatment and post-treatment was -14.997 with computed p-value of 8.787×10^{-18}, which was considered to be significant at the $p < 0.05$ level indicating that there was a statistically significant difference between the Chemistry Achievement pre-test and post-test scores of students in the experimental group. This indicate a complete increase in the cognitive achievement of the participants in the experimental group after the intervention PBL, indicating that PBL has enhanced students‘ cognitive achievement in solving chemistry problems under the selected topics.

Table 4: Independent T-test for Control and Experimental Post-test Scores of Chemistry Achievement Test (CAT)

GROUP	N	DF	Mean	SD	t-value	P-value
Control	45	83	11.82	3.786		
					-13.506	1.172E-22
Experimental	40		22.50	3.464		

Source: Field Data, 2021

From Table 4, the computed p-value 1.172×10^{-22} was less than 0.05 indicating that there was a statistically significant difference between the mean Chemistry Achievement post-treatment scores of the experimental and control groups. There was a statistically significant difference between the experimental and the control groups on their cognitive achievement in solving chemistry problems on the selected topics. This higher mean of the experimental group to the control group was sparked by the intervention problem-based learning approach used as an intervention for the experimental group. The null hypothesis one which states there is no statistically significant difference between the mean chemistry achievement pre-test and posttest scores of students in the experimental group was rejected in the sense that the experimental group exposed to the problem-based learning had greater mean score for the post-test indicating a greater cognitive achievements on the part of the students in the experimental group. As to whether PBL significantly influenced the experimental group performance in chemistry, data from the pre-test and post-test were analyzed using students' t-test, at $p < 0.05$. From Table 2, the mean score for the control and experimental group pretest scores was 21.29 and 12.62 respectively. The t-value from computed t-statistics was 11.920 with p-value of 1.143. The results of the pre-test showed that there was no significant difference between the experimental group and the control group which affirmed that the performance of the groups were similar in solving chemistry problems. From Table 3, the computed data analysis revealed that the mean for the experimental group pre-test and post test scores were 12.62 and 22.50 respectively. The mean difference between the pre-test and posttest scores of the experimental group was 9.88 which indicated a gradation in performance of the experimental group in solving chemistry problems. Also the t-test results for the difference of means in the experimental group pre-test and post-test was -14.997 which was considered to be significant at the $p < 0.05$ level. This indicated that the experimental group performance in chemistry on the post-test was significantly better than their performance in the pre-test. It was assumed that PBL is a speed bump for sparking this massive improvement in the performance of the students' in the experimental group.

From Table 4, the computed data analysis on the posttest scores of the control and experimental revealed that the mean for the control and experimental posttest scores were 11.82 and 22.50 respectively. The mean difference between the posttest scores of the control and experimental group was 10.68 which indicated a complete difference in the performance of the experimental group mean from the pre-test. Also, the t-test results for the difference of means in the control and experimental group post-test was -13.506 which was considered to be significant at the $p < 0.05$ level. This therefore indicated that there was a significant difference in the performance of the control and experimental group posttest scores. This mean that PBL intervention helped to improve the experimental group performance in solving chemistry problems.

The higher mean of Students�to responses to the post-test showed that students in the experimental groups had significantly fewer alternative conceptions and understood the concepts more meaningfully than control groups (Tarhan & Acar, 2007). Since there was a significant difference in the performance of the experimental group exposed to PBL and the control group exposed to conventional approach, it can be concluded that PBL is one of the innovative approaches to enhance the teaching and learning in the senior high school chemistry lessons. As this helps to produce learners who are independent of their knowledge.

This is in support of the study conducted by Aidoo, Boateng, and Ofori (2016) on the effect of problem-based learning on students‘ achievement in chemistry which saw a significant difference between the students‘ in the control group exposed to traditional method and the students‘ in the experimental group exposed to problem-based learning approach. PBL enhances students‘ achievement by promoting their skills and capabilities in applying knowledge, by challenging students to solve problems, by encouraging them in practicing higher order thinking skills, and by directing their own learning (Jonassen & Hung, 2012). This lends credence to the fact that the adoption of a problem –based learning is a strategy which the science teacher can employ to improve the performance of students and their cognitive achievements in chemistry. These findings confirm earlier results obtained by Hussain and Anwar (2017) which revealed that 10^{th} grade students treated by problem-based learning approach were significantly better in achievement test in chemistry than the students treated by traditional methods.

4.5 Research Question 2

What is the differential impact of the problem-based learning approach on male and female students' cognitive achievement in the selected topics in chemistry?

This research questions sought to determine the real impact of the problem-based learning approach on the cognitive achievement of male and female students' in the experimental group. An independent t-test was conducted on the male and female students' scores in the pre-test and post-test; this is represented in Table 5.

Table 5: Independent T-test for Male and Female Students' in the Experimental Group

Experimental Group	N	DF	Mean	SD	t- value	P- value
Males	24		12.79	2.587		
		38			0.8055	0.4255
Females	16		12.06	3.108		

Source: Field Data, 2021

From Table 5, the computed p value of 0.4244 was greater than 0.05 indicating that there was no statistically significant difference between the mean chemistry achievement pretest scores of the male and female students in the experimental group.

An independent sample t-test for the post-test scores in the experimental group is represented in Table 6.

Table 6: Independent Samples T-test for Post -Test Scores in the Experimental Group

Experimental Group	N	DF	Mean	SD	t- value	P- value
Male	24		22.33	3.371		
		38			-0.368	0.714
Female	16		22.75	3.697		

Source: Field Data, 2021

It could be inferred from Table 6, that the computed p value 0.714 was greater than 0.05 i.e ($p > 0.05$) indicating that there was no statistically significant difference between the mean chemistry achievement posttest scores of male and female students‘ in the experimental group. Therefore, the null hypothesis two which states that there is no statistically significant difference between the mean chemistry achievement pretest and posttest scores of male and female students in the experimental group is failed to be rejected. This therefore means that the use of problem-based learning approach had no difference on the impact of students‘ mean chemistry achievement scores either male or female. As a mean of determining the differential impact of the problem-based learning approach on the cognitive achievement of male and female students‘ in the experimental group, the independent t-test at $p < 0.05$ was conducted to establish the differential impact of problem-based learning on the male and female students‘ pre-test and posttest scores. From Table 5, the mean score for the males and females in the experimental group pretest scores was 12.79 and 12.06 respectively. The t-value from computed t-statistics was 0.8055 with p-value of 0.45255. This mean that $p>0.05$ which indicated no significant difference in the performance of males and females students in the experimental group. This insinuated that the performance of male and females‘ students‘ in the experimental group were similar in solving chemistry problems. On the other hand the posttest scores was also analysed statistically using independent t-test to determine the differential impact of PBL on the males and females students in the experimental group. From Table 6, the mean score for the males and females in the experimental group posttest scores was 22.33 and 22.75 respectively. The t-value from computed t-statistics was -0.368 with p-value of 0.714. This mean that $p>0.05$. It was then concluded that there was no significant difference in the performance of males and females students in the experimental group posttest scores. The achievement scores of males and females can be attributed to the changing socio-cultural environment which has widened the scope for equal educational opportunities for both males and females. Problem-based learning has positive impact on the performance of the student irrespective of either male or female. Problem-based learning has the potential of providing a conducive learning environment for the learner which promotes metacognition and self-regulated learning among learners either male or female. Since problem-based learning helps students acquire problem solving skills which encourage lifelong self-learning Students' exposed to PBL have the opportunity to work with authentic problems through several steps used to solving ill-structured problems.

The assumption is that when students solve problems like those encountered in real life, they are likely to improve their ability to solve various types of problems. Many studies have been conducted in an attempt to determine the differential impact of PBL on the gender performance in chemistry. For instance a study conducted by Etiubon and Ugwu (2016) indicated that there is no significant difference between the mean achievement scores of male and female chemistry students taught the concept of thermodynamics using PBL approach. Also a study conducted by Jimoh and Fatokun (2020) on the effect of PBL on chemistry students' achievement and interest in mole concept indicated that gender has no significant effect on students' exposure to PBL since both male and female students had achieved equally. The findings from the empirical studies cited above indicated that the use of the problem-based learning approach promotes students' achievement in chemistry irrespective of their sex.

4.6 Research Question 3

What is the attitude of student towards the use of Problem–based learning as a learning strategy in chemistry?

The researcher used this question to elicit information and clues about the attitudes students' in the experimental group posed when exposed to problem-based learning approach in comparison to their counterpart control group who were exposed to conventional approach. A researcher made experimental group attitude questionnaire was administered to the experimental group after the posttest. The researcher made experimental group attitude questionnaire was divided into three sections and was given to all the forty (40) in the experimental group to complete. The three divisions of the questionnaire were:

- Questionnaire On Student Attitude Towards Problem- Based Learning
- Students Self-Learning And Satisfaction Level In The Selected Topics In Chemistry Using Problem-Based Learning Approach Questionnaires
- Experimental group General views about Problem-Based Learning Questionnaire

Table 7: Questionnaire on Student Attitude towards Problem – Based Learning

S/N	ITEMS	SA 5	A 4	N 3	D 2	SD 1
1	Problem -based learning requires active stimulation of student participation by the teacher	10(25%)	17(42%)	6(15%)	6(15%)	1(3%)
2	The teacher needs to have extensive problem solving knowledge	13(33%)	20(50%)	3(7%)	2(5%)	2(5%)
3	Problem-based learning is one of the keys strategies for creating independent thinkers	7(18%)	15(38%)	6(15%)	7(17%)	5(12%)
4	The teacher presented a problem that motivated me to learn	19(48%)	8(20%)	4(10%)	5 (12%)	4(10%)
5	The teacher only act as facilitator during teaching and learning process	4(10%)	17(42%)	9(23%)	1(2%)	9(23%)
6	The Problem-based learning lesson helped me to apply my knowledge to Solve problems.	25(63%)	10(25%)	3(7%)	2(5%)	0(0%)
7	The problem-based learning lesson encouraged interaction with other students	9(23%)	19(47%)	6(15%)	4(10%)	2(5%)
8	During the problem-based learning lesson I felt as though my opinions were valued	5(13%)	15(38%)	5(12%)	10(25%)	5(12%)
9	I have to take more responsibility for my Learning in problem based learning	11(28%)	13(33%)	8(20%)	5(12%)	3(8%)
10	Problem-based learning takes up more time than conventional lecture based approach	23(58%)	10(25%)	2(5%)	5(12%)	0(0%)

KEY 5 = SA= Strongly Agree, 4 = A= Agree, 3 = N= Neutral 2 = D = Disagree

1 = SD = strongly Disagree

From Table 7 , with reference to questionnaire item 1, it could be seen that out of the 40 students in the experimental group, twenty-seven students representing (68%) of the total students in the experimental group agreed that problem-based learning used by the researcher requires active stimulation of student participation by the teacher, this means, in problem-based learning it is incumbent on the teacher to provide the leaning strategies and act as a facilitator in disseminating the knowledge to the students. Also only seven representing (17%) of the total students in the experimental group disagreed with the questionnaire item. This indicates that most of the student agreed that problem-based learning is a Stimulating approach to be used in teaching and learning of chemistry but the teacher is also required in the process to augment the process of applying it. Also six students representing (15%) of the total number of student in the experimental group were undecided about the questionnaire item. With reference to questionnaire number two thirty-three students, the teacher needs to have extensive problem solving knowledge, this means that the teacher should be reliable and should be more knowledgeable in the field with which PBL approach is to be applied. Only four representing (10%) of the students in the experimental group disagreed with the questionnaire item, whiles only three representing (7%) of the total student in the experimental group were undecided with questionnaire item. With questionnaire item three, twenty-two representing (55%) of the total students in the experimental group agreed with the questionnaire item, twelve representing (30%) of the total population in the experimental group disagreed with the questionnaire item whiles six representing (15%) of the total student in the experimental group were undecided with the questionnaire item.

With questionnaire item 4, 27 (68%) of the total experimental group agreed, nine representing (22%) of the total experimental group also disagreed with the questionnaire item whiles four representing (10%) of the total student in the experimental group also were undecided in choosing a response to item 4 (Table 7). With item 5, 21 (52%) of the students in the experimental group agreed with the questionnaire item (Table 7). 10 (25%) of the total students in the experimental group disagreed with the questionnaire item whiles 9(23%) of the students in the experimental group also were undecided choosing a response to the questionnaire item (Table 7). With item 6, 35 students representing (88%) 0f the total students in the experimental group also agreed with the questionnaire item, two students representing (5%) of the students in the experimental group disagreed with the questionnaire item whiles three students representing (7%) of the total number of students in the experimental group were undecided with response to the questionnaire item (Table 7).

Also with item 7, 28(70%) of the total students in the experimental group agreed with the questionnaire item, 6(15%) of the total students in the experimental group also disagreed with the questionnaire item as well as 6 (15%) of the total students in the experimental group also were undecided in choosing a response to the questionnaire item (Table 7). With item 8, 20(50%) of the total number of students in the experimental group agreed with the item, 15 (38%) of the total number of students in the experimental group disagreed with the questionnaire item as well as 5(12%) of the total number of students in the experimental group were undecided choosing a response to the questionnaire item (Table 7). With item 9, 24(60%) of the total number of students in the experimental group agreed with the questionnaire item, eight students representing (20%) of the total number of students in the experimental group disagreed with the questionnaire item as well as 8 (20%) of the students in the experimental group were undecided in choosing a response to the questionnaire item. Lastly, with questionnaire item 10, 33(83%) of the total number of students in the experimental group agreed with the questionnaire item, 2 (5%) of the total number of students in the experimental group also disagreed with the questionnaire item as well as 5(13%) of the total number of students in the experimental group were undecided about the questionnaire item.

Table 8: Students Self-Learning and Satisfaction Level in the selected Topics in Chemistry using Problem-Based Learning Approach Questionnaires

S/N	ITEM	SD 1	D 2	N 3	A 4	SA 5
1	PBL instructional approach helped to engage and focus my attention on acid, base and redox reaction	2(5%)	3(7%)	2(5%)	6(15%)	27(68%)
2	PBL approach has helped me to develop curiosity for what I already know about the selected topics	1(3%)	2(5%)	5(12%)	7(17%)	25(63%)
3	PBL has helped me to apply my knowledge and understanding to outline some characteristic properties of acid and bases in aqueous solution	0(0%)	4(10%)	2(5%)	4(10%)	30(75%)
4	Through the use of PBL approach I was able to demonstrate knowledge and understanding to describe qualitatively how acid-base indicators work	3(8%)	3(8%)	2(5%)	15(37%)	17(43%)
5	PBL approach has enabled me distinguish between solutions that are acidic, neutral or basic using the pH scale	2(5%)	1(3%)	2(5%)	8(20%)	27(67%)
6	PBL approach enabled me to develop Problem-solving skills relating to pKa and pKb of weak acids and bases	3(7%)	3(7%)	4(10%)	11(28%)	19(48%)
7	PBL approach helped me to easily identify oxidizing and reducing agents in any given redox equations	0(0%)	2(5%)	2(5%)	4(10%)	32(80%)
8	PBL has helped me to develop numeracy and calculation skills involved in balancing any given redox equations for half-reactions and overall reactions	2(5%)	5(12%)	2(5%)	8(20%)	23(58%)
9	Through the use of PBL, I was able to extend and apply my knowledge in Solving more challenging related acid,base and redox reaction problem	0(0%)	3(7%)	2(5%)	7(18%)	28(70%)
10	Through the use of PBL I am confident in my ability to identify and search for information that is needed to solve a	2(5%)	2(5%)	4(10%)	6(15%)	26(65%)

problem in other Chemistry topics

KEY

1= SD = Strongly Disagree, 2 = D = Disagree, 3 = N= Neutral, 4 = A = Agree, 5 = SA = Strongly Agree

From Table 8, it is evident that, with item 1, 33 (83%) of the number of students in the experimental group agreed with the questionnaire item, ‗*the use of PBL instructional approach helped to engage and focus my attention on acid, base and redox reaction",* 5 (12%) of the total number of students in the experimental group also disagreed with the questionnaire item as well as two students representing (5%) of the total number of students in the experimental group were undecided with the questionnaire item (Table 8).

With questionnaire item 2, 32(80%) of the students in the students in the experimental group also agreed with the questionnaire item ―*The use of PBL approach has helped me to develop curiosity for what I already know about the selected topics",* also 3 (7%) of the total number of the students in the experimental group disagreed with the questionnaire item as well as 5 (13%) of the total number of students in the experimental group also were undecided with the questionnaire item (Table 8).

With questionnaire item 3, ―*The use of PBL has helped me to apply my knowledge and understanding to outline some characteristic properties of acid and bases in aqueous solution",* 34 (85%) of the total number of students in the experimental group agreed with the questionnaire item as well as 4(10%) also disagreed with the questionnaire item whereas 2 (5%) of the total number of students in the experimental group were undecided (Table 8). With item 4, ―*Through the use of PBL approach I was able to demonstrate knowledge and understanding to describe qualitatively how* *acid-base indicators work"* , 32(80%) of the total number of students in the experimental group agreed with the questionnaire item, six students representing (15%) of the total number of students in the experimental group also disagreed with the questionnaire item, whereas two students representing (5%) of the total number of students in the experimental were also undecided.

With item 5, *"The use of PBL approach has enabled me distinguish between solutions that are acidic, neutral or basic using the pH scale"*, 35 (88%) of the total number of students in the experimental group agreed with the questionnaire item, 3 (7%) of the total number of students in the experimental group disagreed with the questionnaire item as well as 2(5%) of the total number of students in the experimental group were also undecided (Table 8). With item 6, *"The use of PBL approach enabled me to develop Problem-solving skills relating to pKa and pKb* of weak acids and bases" , 30 (75%) of the students in the experimental group agreed with the questionnaire item, six students representing (15%) of the total number of students in the experimental group disagreed with the questionnaire item whereas four students representing (10%) of the total number of students in the experimental group also were undecided (Table 8). Questionnaire item 7, *"The use of PBL approach helped me to easily identify oxidizing and reducing agents in any given redox equations",* 36 (90%) of the total number of students in the experimental group agreed with the questionnaire item 2(5%) of the total number of students in the experimental group disagreed with the questionnaire item, also two students representing (5%) of the total number of students in the experimental group were undecided with the questionnaire item (Table 8). With item 8, *"The use of PBL has helped me to develop numeracy and calculation skills involved in balancing any given redox equations for half-reactions and overall reactions",* 31(78%) of the total number of students in the experimental group agreed with the questionnaire item, 7(17%) of the total number of students in the experimental group disagreed with the questionnaire item whereas two students representing (5%) of the total number of students in the experimental group were undecided. With item 9, ―*Through the use of PBL, I was able to extend and apply my knowledge in Solving more challenging related acid, base and redox reaction problem*", 35(88%) of the total number of students in the experimental group agreed with the questionnaire item, 3(7%) of the total number of students in the experimental group disagreed with the questionnaire item, two students representing 5% of the students in the experimental group also were undecided. With item ten, ―*Through the use of PBL I am confident in my ability to identify and search for information that is needed to solve a problem in other Chemistry topics",* 32 (80%) of the total number of students in the experimental group agreed with the questionnaire item, 4(10%) 0f the total number of students in the experimental group disagree with the questionnaire item as well as four students representing (10%) of the total number of students in the experimental group also were undecided with the questionnaire item.

Table 9: The Experimental Group General views about Problem-Based Learning Questionnaires

S/N	ITEM	SA 5	A 4	N 3	D 2	SD 1
1	PBL approach give one the ability to become a critical and analytical thinker	18(45%)	13(33%)	4(10%)	4(10%)	1(2%)
2	PBL approach gives the ability to experience different techniques and strategies in solving problems	21(53%)	12(30%)	3(7%)	2(5%)	2(5%)
3	PBL help to develop ability to critically accept and analyse others ideas	11(28%)	19(48%)	7(17%)	0(0%)	3(7%)
4	PBL help one to seek the appropriate information for the task at hand.	20(50%)	13(33%)	4(10%)	2(5%)	1(2%)
5	PBL give one the ability to tackle complex problems	10(25%)	9(23%)	10(25%)	7(17%)	4(10%)
6	PBL approach help to improve one's communication skills	15(37%)	17(43%)	2(5%)	4(10%)	2(5%)
7	PBL help to stimulate continuous acquisition of new and relevant knowledge	19(48%)	15(38%)	3(7%)	3(7%)	0(0%)
8	PBL can be one of the best approach to make teaching and learning of chemistry easier	16(40%)	11(28%)	6(15%)	5(12%)	2(5%)
9	PBL approach is better than the conventional approaches	14(35%)	9(23%)	8(20%)	7(17%)	2(5%)
10	PBL provides opportunity for independent learning and knowledge Construction	12(30%)	10(25%)	5(12%)	9(23%)	4(10%)

KEY

5= SA= Strongly Agree, 4 = A= Agree, 3 = N= Neutral, 2 = D = Disagree, 1 = SD = strongly Disagree

With item one, _*'PBL approach give one the ability to become a critical and analytical thinker''*"31 (78%) of the total number of students' in the experimental group agreed with the questionnaire item, 4 (10%) of the total number of students in the experimental group disagreed with the questionnaire item, five students representing (12%) of the total number of students in the experimental group were undecided with the questionnaire item. Item two, *„PBL approach give the ability to experience different techniques and strategies in solving* problems" with this questionnaire item, thirty three students representing (83%) of the total number of students in the experimental group agreed with the questionnaire item, 3 (7%) of the total number of students in the experimental group disagreed with the questionnaire item whiles four students representing (10%) of the total number of students' in the experimental group were undecided. With item 3, *‗PBL help to develop ability to critically accept and analyse others ideas"*30 (75%) of the total number of students in the experimental group agreed with the questionnaire item, 7 (17%) of the total number of students' in the experimental group disagreed with the questionnaire item, 3 (7%) of the total number of students' in the experimental group were undecided. With item 4, *‗PBL help one to seek the appropriate information for the task at hand"***,** 33(83%) of the total number of students in the experimental group agreed with the questionnaire item, 4(10%) of the total number of students in the experimental group disagreed with the questionnaire item, 3(7%) of the total number of students in the experimental group were undecided about the questionnaire item.

With item 5, *‗"PBL give one the ability to tackle complex problems""*19(48%) of the total number of students in the experimental group agreed with the questionnaire item, 10 (25%) of the total number of students in the experimental group disagreed with the questionnaire item, 11 (27%) of the total number of students in the experimental group were undecided. With item 6, *PBL approach help to improve one"s communication skills""*32 (80%) of the total number of students in the experimental group agreed with the questionnaire item, 2 (5%) of the total number of students in the experimental group disagreed with the questionnaire item, 6(15%) of the total number of students in the experimental group were undecided. Item seven, *_‗PBL help to stimulate continuous acquisition of new and relevant knowledge""* with this questionnaire 34 (85%) of the total number of students in the experimental group agreed with the questionnaire item, 3 (7%) of the total number of students in the experimental group disagreed with the questionnaire item, also 3(8%) of the total number of students in the experimental group were undecided with the questionnaire item. With Item 8, *_‗PBL can be one of the best approach to make teaching and learning of chemistry easier""*27 (68%) of the total number of students in the experimental group agreed with the questionnaire item, 6 (15%) of the total number of students‘ in the experimental group disagreed with the questionnaire item, 7(17%) of the total number of students in the experimental group were undecided with the questionnaire item. With item 9, *_‗PBL approach is better than the conventional approaches""*with this questionnaire item, 23 (58%) of the total number of students in the experimental group agreed with the questionnaire item, 8 (20%) of the total number of students in the experimental group disagreed with the questionnaire item, 9 (22%) of the total number of students in the experimental group were undecided with the questionnaire item. With item 10**,** *PBL provides opportunity for independent learning and knowledge construction,* 22 (55%) of the total number of students in the experimental group agreed with the questionnaire item, 13 (33%) of the total number of students in the experimental group disagreed with the questionnaire item, 5(12%) of the total number of students‘ in the experimental group were undecided about the questionnaire item. Table 7 analysed the students‘ attitude towards problem-based learning using a likert items with scale ranging from strongly agree =5; Agree= 4; neutral=3; disagree=2; and strongly disagree=1; After collating all the responses for the likert items in Table 7 it was analysed descriptively by the use of percentages. This helped in determining the level of agreement in response to a likert item. Attitudes have a significant role in influencing the individuals‘ performance which encourages collaborative sharing of ideas where every student comport himself or herself to either contribute an idea to be shared or learning new things from their counterpart. From Table 7, it was quite evident that students‘ have positive attitude towards PBL. This indicates that students‘ will always like to solve mind intriguing problems in chemistry than always relying on the teacher for knowledge and understanding. Many studies have been conducted on assessing the effectiveness of problem-based learning on students‘ attitude. Akinoglu and Tandogan (2007) conducted a study on the effects of problem-based active learning in science education students‘ academic achievement, attitude and concept Learning, the study saw a significant difference in the attitude of the experimental group exposed to PBL and control group exposed to traditional method. Some of the students‘ interviewed also expressed a positive feeling toward the use of problem-based learning where some of the students‘ opined that the problem-based learning attracted them to develop interest in learning because it starts with solving a problem.

Pirrami (2009) also conducted a study to investigate the impact of PBL on students‘ learning. Questionnaires were administered to assess students' perceptions after the module was completed. Findings showed that students showed positive attitude toward the use of problem-based learning. Also from Table 8, questionnaire on Students self-learning and satisfaction level in the selected topics in chemistry using problem-based learning approach was also administered to the learners in the experimental group after the posttest to determine their level of satisfaction on acid, base and redox reactions. From Table 8, it could be observed that most of the students in the experimental group showed higher agreement with the posed questionnaire items. This indicated that the use of problem-based learning in the selected topics acids, bases and redox reactions proved to be successful. Because PBL deals with mind on and continuous exposure to ill-structured problems, the students in the experimental group developed higher level of performance in the posttest. Analysis of students‘ responses also revealed that problem-based learning approach had a positive influence on the teaching and learning of acids, bases and redox reactions since it helped to adequately revise students‘ prior knowledge on the topics, stimulate their interests, engaged and focused their attention and encouraged them to participate actively in class lessons. The use of the problem-based learning fostered team work and cooperation among students in the experimental group. The successful outcome of PBL on acids, bases and redox reactions indicated that students can also perform better in other chemistry topics when PBL in correctly applied. Lastly questionnaire on the experimental group general views about PBL in Table 9 was administered to peruse generalized idea of students‘ exposed to the PBL approach. The collated results on the questionnaire items indicated a higher level of percentage in agreement to a questionnaire item. The higher level of percentage with respect to agreement indicated that the students‘ in the experimental group enjoyed the PBL approach and they will like to use it again in teaching other topics in chemistry. PBL challenged their mode of thinking in relation to problems set in the classroom as well as improving their interactive skills through close association with other group members. Findings from the researcher‘s analysis and interpretation evidently showed that PBL has positive impact on the attitude of students‘ and therefore students‘ exposed to the approach showed positive attitude and perceptions as well as positive generalization about PBL.

4.7 Research Question 4

What conceptual difficulties do senior high school Students have in solving chemistry problems?

Research question four sought to identify some difficulties the students in the control and experimental group had in solving chemistry problems. The researcher used the selected topics that is acids, bases and redox reactions as a speed bump in identifying some difficulties students in the control and experimental group had in solving chemistry problems. Although these difficulties were not generalized as a problem students' have in solving chemistry problems but it helped the researcher to identify some little difficulties which the students had which were so easy to solve. In identifying some difficulties, the researcher listed some difficulty levels and compared them to how students in the control and experimental group answered questions during the pre-test and post -test.

Table 10: Identified Student difficulty Levels in Solving Chemistry Problems during the Pretest

Nature of Difficulty Students	Control Group (45) Number of Students and Percentage		Experiemental Group (40) Number of Students and Percentage
1. Writing formulas of compounds correctly	Unable to write	13(29%)	28(70%)
	Able to write	32(71%)	12(30%)
2. Identification of elements and their atomic numbers	Unable to identify	19(42%)	23(57%)
	Able to identify	26(58%)	17(43%)
3. Writing symbols of some Elements	Unable to write	23(51%)	25(63%)
	Able to write	22(49%)	15(37%)
4. Writing chemical formulas of compounds	Unable to write	21(47%)	25(63%)
	Able to write	24(53%)	15(37%)

5. Computational errors	Unable to compute	29(64%)	27(68%)
	Able to compute	16(36%)	13(32%)
6. Balancing chemical equations	Unable to balance	19(42%)	28(70%)
	Able to balance	26(58%)	12(30%)
7. Wrong use of units	Wrong use of units	17(38%)	29(73%)
	Correct use of units	28(62%)	11(27%)
8. Inability to write charges of elements	Unable to write	15(33%)	28(70%)
	Able to write	30(67%)	12(30%)
9. Inability to differentiate between Atoms and Compounds	Unable to differentiate	20(44%)	22(55%)
	Able to differentiate	25(56%)	18(45%)
10. Inability to calculate oxidation numbers of compounds	Unable to calculate	15(33%)	26(65%)
	Able to calculate	30(67%)	14(35%)

Graphical interpretation of difficulty levels of the control group in the pre-test is presented in Figure 6.

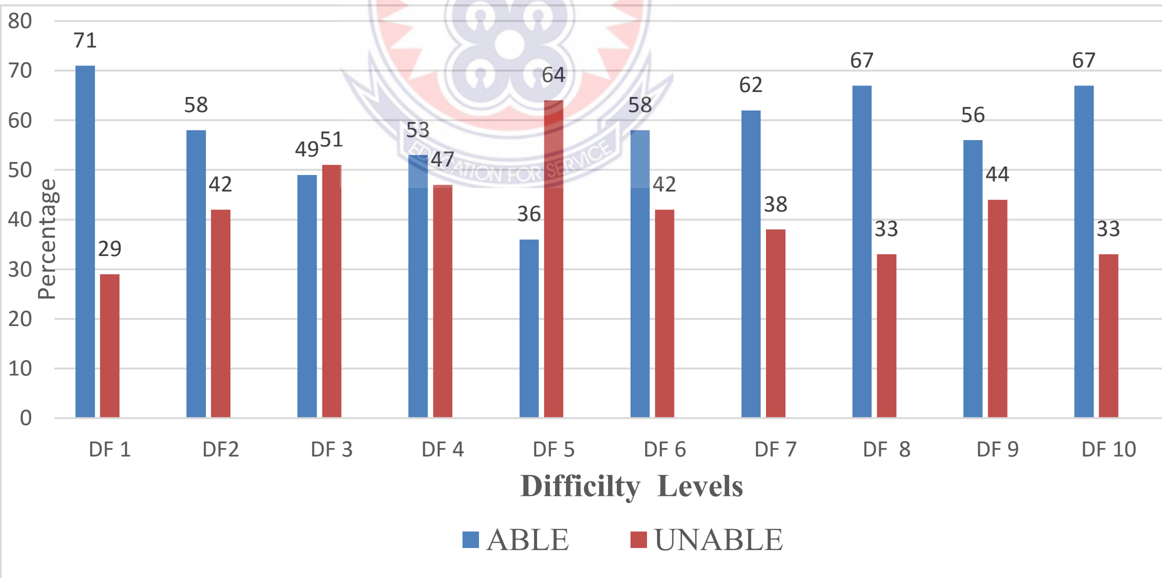

Figure 6: Difficulty Levels of the Control Group in the Pretest

It could be inferred from Figure 6, that most of the students in the control group were able to solve chemistry problems in the pre-test by overcoming some of the identified difficulties by the researcher. With difficulty level five, twenty (26) students representing (64%) of the total number of students in the control group were unable to compute figures into formula to get correct answers most of the students in the control group had a problem in computing and calculating to get the correct answers. The researcher observed during the marking of script that, most of the students in the control group could not compute to solve the $_{P}H$ of a solution. Most of them could not differentiate between $_{P}H$ and $_{P}OH$ of solutions. This indicates that most science students have difficulty in computing into formulas to get correct answers.

Graphical interpretation of difficulty levels of the experimental group in the pre-test is presented in Figure 7.

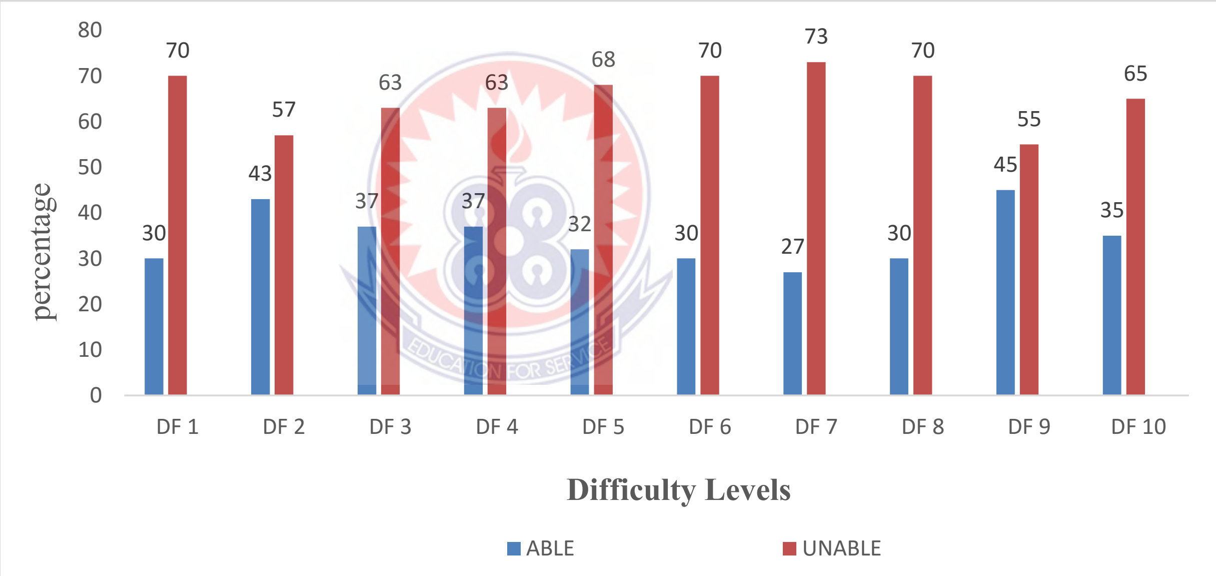

Figure 7: Difficulty Levels of the Experimental Group in the Pre- Test

Also from Figure 7, it could be inferred that, most of the students in the experimental group had problems in solving chemistry problems in the pre-test with the difficulty levels outlined by the researcher. Most of the students in the experimental group could not even differentiate between the first twenty elements and their symbol with some writing different symbols for some elements. Also most of the students in the experimental group could not balance any chemical equations as well as identifying an element and its atomic number. This abysmal performance of the students in the pre-test informed the researcher about the need for the treatment, using PBL to solve some difficulty levels in aicds, bases and redox reactions.

Table 11: Identified Student Difficulty Levels in Solving Chemistry Problems during the Posttest

Nature of Difficulty Students	Control Group (45) Number of Students and Percentage		Experimental Group(40) Number of Students and Percentage
1. Writing formulas of compounds correctly	Unable to write	19(42%)	14(35%)
	Able to write	26(58%)	26(65%)
2. Identification of elements and their atomic numbers	Unable to identify	19(42%)	9(22%)
	Able to identify	26(58%)	31(78%)
3. Writing symbols of some Elements	Unable to write	28(62%)	2(5%)
	Able to write	17(38%)	38(95%)
4. Writing chemical formulas of compounds	Unable to write	22(49%)	11(27%)
	Able to write	23(51%)	29(73%)
5. Computational errors	Unable to compute	27(60%)	16(40%)
	Able to compute	18(36%)	24(60%)
6. Balancing chemical equations	Unable to balance	25(56%)	15(37%)
	Able to balance	20(44%)	25(63%)
7. Wrong use of units	Wrong use of units	17(38%)	8(20%)
	Correct use of units	28(62%)	32(80%)
8. Inability to write charges of elements	Unable to write	19(42%)	7(18%)
	Able to write	26(58%)	33(82%)
9. Inability to differentiate between Atoms and Compounds	Unable to differentiate	21(47%)	14(35%)
	Able to differentiate	24(53%)	26(65%)

10. Inability to calculate oxidation numbers of compounds	Unable to calculate Able to calculate	17(38%) 30(62%)	13(32%) 27(68%)

Graphical interpretation of difficulty levels of the control group in the post-test is presented in Figure 8.

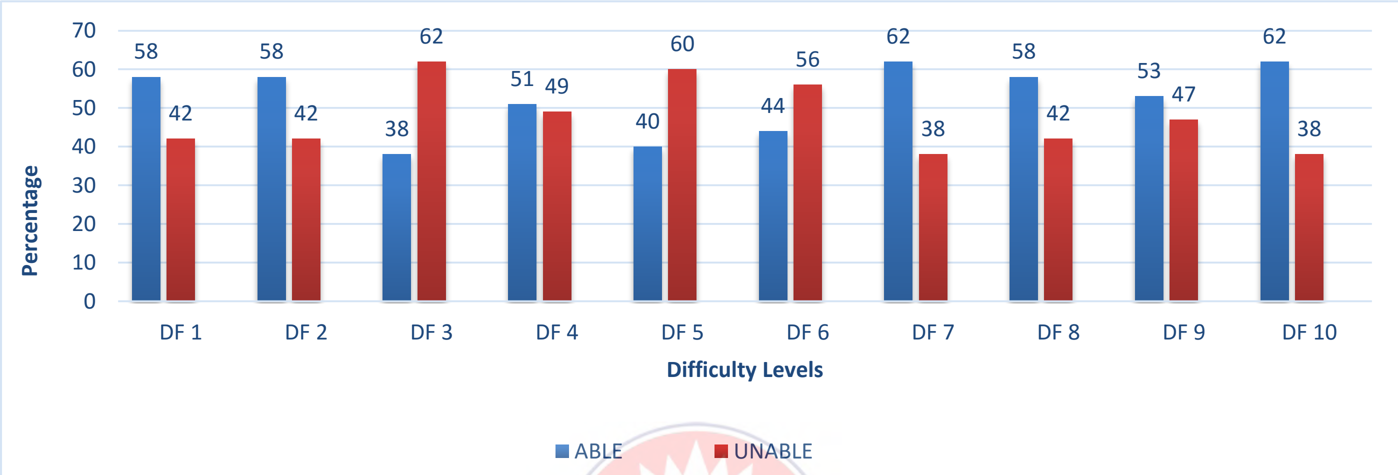

Figure 8: Difficulty Levels of the Control Group in the Post Test

From Figure 8, it is evident that there was a flop in performance of the of the students in the control group in some of the identified difficulty levels during the pre-test while other difficulty levels saw no change in attitude on the students in the control group.

Graphical interpretation of the difficulty levels of experimental group in the posttest is presented in Figure 9.

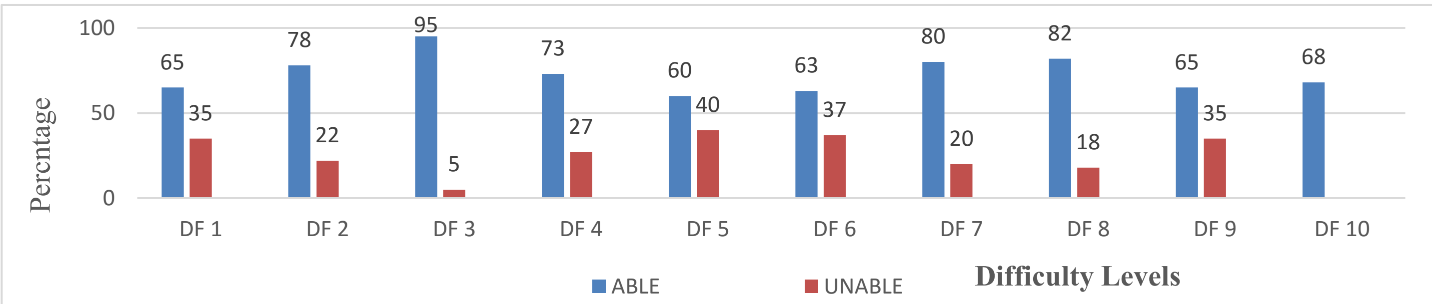

Figure 9: Difficulty Levels of the Experimental Group in the Post-test

It could also be inferred from Figure 9, that the experimental group exposed to treatment called problem-based learning approach in teaching chemistry saw a great improvement in cognitive achievement in solving chemistry problems. This indicates that, problem-based learning is one of the approaches to be employed by the chemistry teacher in teaching abstract concepts in chemistry. This is because problem-based learning considers the learning needs of every student and make them the owner of their own knowledge. Problem-based learning also informs the learner that it is incumbent on them to learn and the teacher is only there as a guide. The control group who were exposed to conventional approaches in teaching chemistry did not improve in most of these difficulties in the post test. One of the key competences regarded as critical in science and chemistry education is the ability to solve chemical problems. The researcher gathered some evidence of difficulties students‘ in the control and the experimental group had in solving chemistry problems. Some of the causes of the identified difficulties was that students in the control and experimental group lack conceptual understanding of the basic concepts in chemistry. For instance a student writing ―S" as a symbol for sodium inferred that most of the students‘ were not even familiar with the elements in chemistry. The academic performance of students in any subject serves as an important indicator of the quality and effectiveness of teaching and learning which in turn can be used as an index to determine the extent to which educational objectives in the intended subject are being attained (Shadreck & Enunuwe, 2017). The researcher observed that some of the difficulties students‘ have in solving chemistry problems was as a result of misconceptions students‘ had regarding the elements in chemistry and their symbols, balancing equations, stoichiometric concepts such as the mole concept, superscripts and coefficients. The researcher also observed that the limited proficiency of students‘

in mathematics also contributed to the difficulties they encountered when computing to solve chemistry problems. The researcher identified some of these problems students‘ in the control and experimental group have by scrutinizing their scripts after the pre-test and posttest of the chemistry achievement test. Some of the identified problems were listed and analysed using percentages in the pretest and posttest. The researcher did not generalize these difficulties as the difficulties students‘ have in solving chemistry problems, but it helped the researcher to get a firsthand experience of some little difficulties students‘ have in solving chemistry problems.

Because students‘ perceived chemistry to be a complex and conceptually difficult subject in the school curriculum, it becomes critically important for chemistry educators to be aware of the difficulties students encounter as they learn the subject so that appropriate measures can be taken to address these difficulties (Gegios, Salta & Koinis 2017). From Table 10, some of the difficulties identified in the pretest was collated and analysed using percentages. It could be inferred from Table 10 that most of the students‘ in the experimental group had low percentages with respect to the identified difficulties students‘ had in solving chemistry problems during the pretest with the control group getting higher percentages in some of the identified difficulties. It was therefore of importance that an appropriate instructional approach be adopted in overcoming some of these difficulties students‘ in the experimental group had in solving chemistry problems. The experimental group was therefore taken through intervention package problem-based learning approach where the researcher gave the students‘ in the experimental group more tasks on the identified difficulties and checked from time to time. It is of great importance that student should be familiar with the language of chemistry so that they can easily solve problems in chemistry. In this connotation, students were given tasks to perform alongside the use of PBL in teaching acids, bases and redox reactions. Students in the experimental group were given tasks on knowing chemical symbols of elements, knowing the difference between ions, atoms, molecules and compound, balancing chemical equations. The students‘ in the control group were not taken through any intervention. The researcher did not help the students‘ in the experimental group in just taking tasks in the aforementioned difficulties but he guided them to think on how chemical equation is balanced which helped them to easily balance other chemical equation that was given to them. After the intervention, the posttest was administered to the control and experimental group. It could be inferred from Table 11 that most of the students‘ in the experimental group overcame some of the identified difficulties by getting higher percentages than their counterparts in the control group. The researcher concluded that the higher performance of the students‘ in the experimental group was due to the appropriate teaching method used in solving the identified difficulties.

4.8 Chapter Summary

The study has gathered evidence supporting the view that the recurrent problems senior high school students‘ have in solving chemistry problems can be addressed using PBL approach. Secondly, problem-based learning instruction is more effective and superior to conventional approach in remedying students‘ cognitive achievements in chemistry. The results of the study further demonstrate the superiority of problem-based learning instruction to the conventional approach method in solving chemistry problems. It is therefore appropriate that the use of PBL should be encouraged as one of the best instructional approach that can be implemented to address the cognitive achievements of students‘ in the senior high schools in solving chemistry problems.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.0 Overview

This chapter provides the summary of the research findings, conclusions and the recommendations from the study. The discussions, conclusions and recommendations were made in accordance with the purpose of the study and research objectives. Finally, the areas for further research are suggested for consideration in future studies.

5.1 Summary of Findings

Two groups were used in the study that is, the control and experimental group. The Study further developed the means for the scores for the control and experimental groups in both the pre-test and post-test which suggested a differences between the pairs. In achieving researcher�Vs objective one, which intended to i*nvestigate the extent to which the use of Problem-based learning will enhance students" performance in chemistry,* considered pre-test and posttest scores of the control and experimental group. For the pre-test, an unpaired t-test was done to show the significant difference between the experimental and the control groups. It was premised on the notion that for any experimental research the entry behavior for control and experimental groups ought to be the same. The computed p-value 1.143 was not significant at p = 0.05. This implies that there was no significant difference between the pre-intervention test scores for the control and experimental groups.

Thus the learners‘ in the control and experimental group entry behaviors were found to be similar before the intervention problem-based learning approach. Also the posttest scores of the control and experimental group was also analysed using unpaired and paired t-test. The unpaired t-test was used to establish the significant difference between the posttest scores of the control and the experimental groups. The paired t-test was also used to establish the significant difference between the pre-test and post test scores of the experimental group. The analysed unpaired t-test for the control and experimental group pre-test and posttest scores was significant at p = 0.05 since the computed p-value of 1.172×10^{-22} was less than the significant level p= 0.05.

The significant difference between the pre-test and posttest scores of the control and experimental group indicated a significant difference between the pre-intervention test and the post-intervention scores of the control and the experimental group. Also the anlaysed paired t-test was used to determine if there was a significant difference between the mean scores of the pre-test and posttest scores of the experimental group. The experimental group pre-test mean was found to be 12.62 whiles the posttest mean score was 22.50 indicating a mean difference of 9.88. The computed t- value was -14.997 with p-value of 8.78×10^{-18} which indicated a significant difference between the experimental group pretest and posttest. The higher mean difference between the experimental group pretest and posttest scores was assumed to be the effectiveness of PBL which was used as an intervention for the experimental group. Also unpaired t-test was carried out to determine if there was significant difference between the posttest scores of the control and the experimental group.

The control group mean was found to be 11.82, whiles the experimental group mean was also found to be 22.50 indicating a mean difference of 10.68 for the experimental and control group posttest scores. The computed t-test was 13.506 and a p-value of 1.172×10^{-22} which was considered to be significant at p = 0.05. Also in achieving the researcher‵s stated objective two which intended to ascertain the differential impact of the problem-based learning approach on male and female students‵ cognitive achievement in the selected topics in chemistry, the independent t-test conducted for the pre-test and posttest score of the males and females students‘ in the experimental group saw no significant difference between male and female students exposed to problem-based learning approach.

With researcher‘s objective three which also intended to investigate if the use of PBL will enhance students‘ attitude towards chemistry problems, the descriptive analysis on all the questionnaires indicated that students‘ have positive attitude towards PBL approach when properly applied in teaching and learning of chemistry. Lastly the descriptive analysis done in achieving the researcher‘s objective four in *identifying the difficulties senior high school students encounter in solving chemistry problems* yielded a positive response in favour of the experimental group exposed to problem-based learning than the control group exposed to the conventional approach. The students‘ in the experimental group exposed to the PBL approach overcame some of these difficulties than their counterparts in the control group who were exposed to the conventional approach of teaching and learning chemistry.

5.2 Implications of the Findings

- Statistical significant difference existed between the mean chemistry achievement pretest and posttest scores of the experimental group. Since the mean chemistry achievement posttest score of the experimental group was significantly higher than the mean pretest score, suggests that the problem-based learning approach intervention positively affected the experimental group performance chemistry. The study predicts that with full implementation of problem-based learning approach, students‘ are likely to perform better in chemistry and improve their cognitive achievements in chemistry.

- The study has revealed that there was no statistically significant difference between the mean chemistry achievement pretest and posttest scores of the male and female students in the experimental group. This therefore indicated that the problem-based learning approach had no differential impact on the student's cognitive achievements in acid, base and redox reaction as a selected topics used for the research based on their gender. This therefore gives a clear cut that problem-based learning have no differential impact on the performance of male or female students, it rather work well for all student gender when properly applied.

- The use of problem–based learning approach had a positive effect on the teaching and learning of chemistry as well as helping students' develop positive attitude toward solving chemistry problems. This implies that if a problem-based learning approach is reinforced in the teaching and learning of chemistry the effects of productive change in students' perception and attitude towards teaching and learning of chemistry will be realised in the science classrooms. This conclusion was derived based on the evaluation of students' responses on the problem-based learning attitude questionnaire administered to the students in the experimental group.

The findings made from the analyses of data gathered in the study indicated that students' taught concepts in acids, bases and redox reactions using PBL approach had a comparatively higher achievement in solving chemistry problems than those exposed to conventional approach of teaching and learning chemistry. Therefore the implication is that if problem-based learning is enforced as one of the best teaching methodology by the chemistry teachers in the Senior High Schools in Ghana the challenges of poor performance and negative attitude of students' towards chemistry will be a thing of the past. Also, there was a disparity of impact on the achievement of students in chemistry on the basis of their gender. With respect to the above findings and the results obtained on the analyses of the collected data, null hypothesis one and two stated were rejected.

5.3 Conclusions

This study was about the effects of problem-based learning approach on students' cognitive achievement in some selected topics in chemistry. The following conclusions were drawn on the basis of statistical analysis and the findings of the study.

Firstly, the results of the study imply that students exposed to PBL approach in teaching and learning of chemistry saw a great cognitive achievement in solving and understanding of chemistry concepts than students exposed to conventional approach. This was based on the premise of the higher mean of students in the experimental posttest scores than the control group posttest scores. It was therefore concluded that students' exposed to problem-based learning approach performs better in solving chemistry problems than students exposed to conventional approach.

Secondly, the analysis of the mean chemistry achievement test scores of male and female students in the experimental group pointed out that the use of PBL approach in teaching chemistry has no differential effect on students' achievement in chemistry whether male or female. This conclusion was made based on the fact that no significant difference existed between the mean chemistry achievement pretest and posttest scores of male and female students in the experimental group exposed to problem-based learning approach. It was then concluded that, problem-based learning has no discriminatory factor on the sex of the student. It is therefore suitable for improving the cognitive achievement of both male and female students'.

Lastly, the positive response from the analysed problem-based learning attitude questionnaires, where more than half of the students' in the experimental group agreed to the fact that PBL helped them to shape their attitude and perceptions towards chemistry, indicated that PBL is one of the best approaches to evoke the attitude and perception of students‘ towards chemistry which is perceived to be a difficult subject. The study concludes that a problem-based learning approach if effectively implemented has the potential of making learners perform better in solving chemistry problems as well as shaping students‘ attitude towards chemistry.

5.4 Recommendations

Based on the findings of this study, the following recommendations were made:

1. Chemistry teachers‘ at Nkrankwanta Senior High School Technical School should be trained in the use of a problem-based learning approach in teaching chemistry and implement this approach in teaching science students‘ in the school. It was mentioned severely in this study that the fulcrum to raising students‘ achievement in science mostly depends on higher quality instructional approach use in teaching. Students who receive sound and appropriate instruction acquire more knowledge than their peers without such instruction. It will therefore be more appropriate if an engaging instructional approach like PBL is considered in the teaching and learning of chemistry at Nkrankwanta Senior High Technical School.

2. The study recommends that science teachers‘ at Nkrankwanta Senior High Technical School should be provided with appropriate teaching and learning resources, and financial motivation, to enable them to fully implement whole heartedly the use of a problem-based approach in teaching chemistry content and pedagogy.

3. The problem-based learning approach was found in this study to be gender friendly irrespective of the student‘s sex since it did not have any discriminatory effect on students‘ achievement in chemistry. The study recommends that

authorities at Nkrankwanta Senior High Technical School should encourage and sensitize females to venture into science programme than venturing into the General Art and other programme. The PBL instructional approach is therefore highly recommended to be incorporated in the teaching and learning of science especially across all the classes in Nkrakwanta Senior High Technical School and even extended to other subject areas.

4. The Vision 2020 of Ghana outlines that the government should substitute teaching methods that promote inquiry and problem-solving for those based on rote learning. it against this vision and the findings from the study that recommends that science teachers at Nkrankwanta Senior High Technical should employ innovative teaching method like problem-based learning approach during science lessons to enable students' enjoy science lessons and discover things for themselves rather than sticking to archaic teaching and learning methodologies which only provides students' with notes and increase rote learning.

5.5 Suggestion for Further Studies

The results gathered from the study indicated the positive outcomes that problem-based learning had on students' cognitive achievements in chemistry. More of this study and varied kinds must be researched into from the basic to advanced levels of our educational system in all subjects, especially chemistry. A study on investigating how a problem-based learning approach can be used to change the perceptions and attitude of Senior High School students' should be considered.

Also there is a need for further studies to be carried out to investigate the effect of the problem-based learning approach on students' science process skills acquisition. Lastly similar studies ought to be carried out to investigate the impact of problem-based learning on students' cognitive achievement in other chemistry related concepts that were not covered in this study.

REFERENCES

Abanikannda, M. (2016). Influence of problem-based learning in chemistry on academic achievement of high school students in Osun State, Nigeria. *International Journal of Education, Learning and Development, 4*(3), 55-63.

Abdullah, N. A., Hasan, S., & Osman, N. (2013). Role of CA-EDTA on the synthesizing process of cerate-zirconate ceramics electrolyte. *Journal of Chemistry, 2013*.

Achilles, C., & Hoover, S. (1996). Exploring Problem-Based Learning (PBL) in Grades 6-12.

Adesoji, F. A., & Olatunbosun, S. M. (2008). Student, teacher and school environment factors as determinants of achievement in senior secondary school chemistry in Oyo State, Nigeria. *Journal of International Social Research, 1*(2).

Adeyemi, B. A. (2008). Effects of cooperative learning and problem-solving strategies on junior secondary school students' achievement in social studies.

Aidoo, B., Boateng, S. K., Kissi, P. S., & Ofori, I. (2016). Effect of Problem-Based Learning on Students' Achievement in Chemistry. *Journal of Education and Practice, 7*(33), 103-108.

Ajayi, V. O., & Ogbeba, J. (2017). Effect of gender on senior secondary chemistry students‘ achievement in stoichiometry using hands-on activities. *American Journal of Educational Research, 5*(8), 839-842.

Akpan, B. B. (1994). Implementing Science and Technology Education for All: Guide to Better Policy and Practice for Teachers.

Albanese, M. A., & Mitchell, S. (1993). Problem-based learning: A review of literature on its outcomes and implementation issues. *Academic Medicine-Philadelphia-, 68*, 52-52.

Ali, A. (2006). Conducting research in education and the social sciences. *Enugu: Tashiwa Networks Ltd*, 65.

Alkan, F. (2016). Experiential learning: Its effects on achievement and scientific process skills. *Journal of Turkish Science Education, 13*(2), 15-26.

Allen, D. E., Duch, B. J., & Groh, S. E. (1996). The power of problem- based learning in teaching introductory science courses. *New Directions For Teaching and Learning, 1996*(68), 43-52.

Amedahe, F. K. (2001). Combining teacher-assessment scores with external examination scores for certification: The Ghanaian experience. *Educational Measurement, 20*(4), 29-30.

Anzul, M., Ely, M., Freidman, T., Garner, D., & McCormack-Steinmetz, A. (2003). *Doing qualitative research: Circles within circles*: Routledge.

Arambula-Greenfield, T. (1996). Implementing problem-based learning in a college science class. *Journal of College Science Teaching, 26*(1), 26-30.

Araz, G. (2007). *The effect of problem-based learning on the elementary students' achievement in genetics.* Middle East Technical University.

Association, N. S. T. (2003). Standards for science teacher preparation. *Faculty Publications: Department of Teaching, Learning and Teacher Education*, 86.

Auger, W. E., & Rich, S. (2006). *Curriculum theory and methods: Perspectives on Learning and Teaching*: J. Wiley & Sons Canada.

Ausubel, Novak, & Hanesian. (1968). Educational psychology: A cognitive view. A cognitive view (Vol.6). New York : Holt, Rinehart and Winston.

Ausubel, D. G. (1963). Cognitive structure and the facilitation of meaningful verbal learning1. *Journal of Teacher Education, 14*(2), 217-222.

Ayyildiz, Y., & Tarhan, L. (2018). Problem-based learning in teaching chemistry: enthalpy changes in systems. *Research in Science & Technological Education, 36*(1), 35-54.

Barab, S., Dodge, T., Thomas, M. K., Jackson, C., & Tuzun, H. (2007). Our designs and the social agendas they carry. *The Journal of the Learning Sciences, 16*(2), 263-305.

Barron, B., & Darling-Hammond, L. (2008). Teaching for Meaningful Learning: A Review of Research on Inquiry-Based and Cooperative Learning. Book Excerpt. *George Lucas Educational Foundation*.

Barrows, H. S. (1986). A taxonomy of problem- based learning methods. *Medical education, 20*(6), 481-486.

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House, 83*(2), 39-43.

Berry, W. (2008). Surviving lecture: A pedagogical alternative. *College Teaching, 56*(3), 149-153.

Blaxter, L., Hughes, C., & Tight, M. (1997). Education, work and adult life: how adults relate their learning to their work, family and social lives. *Adult Learning: A reader*, 135-147.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist, 26*(3-4), 369-398.

Boaler, J. (2002). Learning from teaching: Exploring the relationship between reform curriculum and equity. *Journal for Research in Mathematics Education, 33*(4), 239-258.

Bonk, C. J., & King, K. S. (2012). Searching for learner-centered, constructivist, and sociocultural components of collaborative educational learning tools *Electronic Collaborators* (pp. 61-86): Routledge.

Booth, R. D., & Thomas, M. O. (1999). Visualization in mathematics learning: Arithmetic problem-solving and student difficulties. *The Journal of Mathematical Behavior, 18*(2), 169-190.

Brooks, J. G., & Brooks, M. G. (1999). *In search of understanding: The case for constructivist classrooms*: Ascd.

Brown, T. H. (2006). Beyond constructivism: Navigationism in the knowledge era. *On the Horizon*.

Burgess, K. L. (2004). Is your case a problem? *Journal of STEM Education: Innovations and Research, 5*(1).

Camp, G. (1996). Problem-based learning: A paradigm shift or a passing fad? *Medical Education Online, 1*(1), 4282.

Cavallo, A. M., Potter, W. H., & Rozman, M. (2004). Gender differences in learning constructs, shifts in learning constructs, and their relationship to course achievement in a structured inquiry, yearlong college physics course for life science majors. *School Science and Mathematics, 104*(6), 288-300.

Chapman, D. W. (2002). Words that make a difference: Problem-based learning in communication arts courses. *The Journal of General Education, 51*(4), 257-271.

Charif, M. F. (2010). *The effects of problem based learning in chemistry education on middle school.(c2010).* Lebanese American University.

Checkley, K. (1997). Problem-based learning: The search for solutions to life‘s messy problems. *Curriculum Update, 1*(6–8), 109-113.

Chen, Y.-H., Rendina-Gobioff, G., & Dedrick, R. F. (2007). Detecting Effects of Positively and Negatively Worded Items on a Self-Concept Scale for Third and Sixth Grade Elementary Students. *Online Submission*.

Chin, C., & Chia, L.-G. (2004). Implementing project work in biology through problem-based learning. *Journal of biological education, 38*(2), 69-75.

Chin, C., & Chia, L. G. (2004). Problem- based learning: Using students' questions to drive knowledge construction. *Science education, 88*(5), 707-727.

Chin, C., & Chia, L. G. (2006). Problem- based learning: Using ill- structured problems in biology project work. *Science Education, 90*(1), 44-67.

Cobern, W. W. (1996). Worldview theory and conceptual change in science education. *Science education, 80*(5), 579-610.

Cockrell, K. S., Caplow, J. A. H., & Donaldson, J. F. (2000). A context for learning: Collaborative groups in the problem-based learning environment. *The Review of Higher Education, 23*(3), 347-363.

Cohen, E. G. (1994). Restructuring the classroom: Conditions for productive small groups. *Review of Educational Research, 64*(1), 1-35.

Cole, S. O. (1986). Effects of benzodiazepines on acquisition and performance: a critical assessment. *Neuroscience & Biobehavioral Reviews, 10*(3), 265-272.

Cooke, M., & Moyle, K. (2002). Students' evaluation of problem-based learning. *Nurse Education Today, 22*(4), 330-339.

Corden, R. (2001). Group discussion and the importance of a shared perspective: Learning from collaborative research. *Qualitative Research, 1*(3), 347-367.

Creswell, J. W. (2002). *Educational research: Planning, conducting, and evaluating quantitative*: Prentice Hall Upper Saddle River, NJ.

Curry, J. (2002). Problem-based learning pathway student handbook. *Columbus: The Ohio State University, College of Medicine and Public Health*.

Danili, E., & Reid*, N. (2004). Some strategies to improve performance in school chemistry, based on two cognitive factors. *Research in Science & Technological Education, 22*(2), 203-226.

DeBacker, T. K., & Nelson, R. M. (2000). Motivation to learn science: Differences related to gender, class type, and ability. *The Journal of Educational Research, 93*(4), 245-254.

Derry, S. J. (1996). Cognitive schema theory in the constructivist debate. *Educational Psychologist, 31*(3-4), 163-174.

Derry, S. J. (1999). A fish called peer learning: Searching for common themes. *Cognitive perspectives on Peer Learning, 9*(1), 197-211.

Dewey, J. (1923). *Democracy and education: An introduction to the Philosophy of Education*: Macmillan.

Dods, R. F. (1996). A problem-based learning design for teaching biochemistry. *Journal of Chemical Education, 73*(3), 225.

Dombrowski, L. (2002). Students generating web pages: Implementation of problembased learning in the classroom. *Educators' Outlook*.

Driver, R., Leach, J., Scott, P., & Wood-Robinson, C. (1994). Young people's understanding of science concepts: Implications of cross-age studies for curriculum planning.

Duckworth, E. (2009). Helping students get to where ideas can find them. *The New Educator, 5*(3), 185-188.

Dyson, A. H. (2000). Writing and the sea of voices: Oral language in, around, and about writing. *Perspectives on writing: Research, Theory, and Practice*, 45-65.

Eggen, P. D., & Kauchak, D. P. (1999). *Video Guide to Accompany Educational Psychology: Windows on Classrooms*: Merrill.

Emendu, N. B. (2014). The role of chemistry education in national development. *International Journal of Engineering and Sciences (IJES), 3*(3), 12-17.

Ernest, P. (1999). Social constructivism as a philosophy of mathematics: Radical constructivism rehabilitated. *A ,,historical paper"avalable at www. people. ex. ac. uk/PErnest*.

Etiubon, R. U., & Ugwu, A. N. (2016). Problem-Based Learning and Students' Academic Achievement on Thermodynamics: A Case Study of University of Uyo, Akwa-Ibom State, Nigeria. *IOSR Journal of Research & Method in Education (IOSR-JRME), 6*(5), 36-41.

Etwistle, N., & Ramsden, P. (1983). Understanding Student Learning (London, Croom Helm). *ENTWISTLE, NJ. & WILSON, J.(1977) Degrees of Excellence: the academic achievement game (London, Hodder & Stoughton)*.

Evensen, D. H., Hmelo, C. E., & Hmelo-Silver, C. E. (2000). *Problem-based learning: A research perspective on learning interactions*: Routledge.

Ferreira, M. M., & Trudel, A. R. (2012). The impact of problem-based learning (PBL) on student attitudes toward science, problem-solving skills, and sense of community in the classroom. *Journal of Classroom Interaction*, 23-30.

Festus, C., & Ekpete, O. (2012). Improving students' performance and attitude towards chemistry through problem-based-solving techniques (pbst).

International Journal of Academic Research in Progressive Education and Development, 1(1), 167-174.

Finucane, P. M., Johnson, S. M., & Prideaux, D. J. (1998). Problem- based learning: its rationale and efficacy. *Medical Journal of Australia, 168*(9), 445-448.

Fletcher, J. (2005). Constructivism and mathematics education in Ghana. *Mathematics connection, 5*, 29-36.

Fosnot, C. T. (2013). *Constructivism: Theory, perspectives, and practice*: Teachers College Press.

Fyrenius, A., Bergdahl, B., & Silén, C. (2005). Lectures in problem-based learning—Why, when and how? An example of interactive lecturing that stimulates meaningful learning. *Medical Teacher, 27*(1), 61-65.

Gallagher, S. A. (1997). Problem-based learning: Where did it come from, what does it do, and where is it going? *Journal for the Education of the Gifted, 20*(4), 332-362.

Gallagher, S. A., Sher, B. T., Stepien, W. J., & Workman, D. (1995). Implementing problem- based learning in science classrooms. *School Science and mathematics, 95*(3), 136-146.

Gegios, T., Salta, K., Koinis, S. (2017). Investigating high-school chemical kinetics: the Greek chemistry textbookand students' difficulties. *Chemistry Education Research and Practice, 18(1), 151-168.*

Gijselaers, W. H. (1996). Connecting problem-based practices with educational theory. *New directions for teaching and learning*, 13-22.

Goodnough, K. C., & Hung, W. (2008). Engaging teachers' pedagogical content knowledge: Adopting a nine-step problem-based learning model. *Interdisciplinary Journal of Problem-Based Learning, 2*(2), 6.

Greening, T. (1998). Scaffolding for success in problem-based learning. *Medical Education Online, 3*(1), 4297.

Greenwald, N. L. (2000). Learning from problems. *The Science Teacher, 67*(4), 28-32.

Groh, S. E. (2001). Using problem-based learning in general chemistry. *The power of problem-Based Learning*, 207-222.

Guedri, Z. (2001). Problem-based learning: Bringing higher order thinking to business schools. *Cahier de recherche OIPG no, 2*.

Günter, T., & Alpat, S. K. (2017). The effects of problem-based learning (PBL) on the academic achievement of students studying ‗Electrochemistry'. *Chemistry Education Research and Practice, 18*(1), 78-98.

Haidar, A. H., & Abraham, M. R. (1991). A comparison of applied and theoretical knowledge of concepts based on the particulate nature of matter. *Journal of Research in Science Teaching, 28*(10), 919-938.

Hale, M., & City, E. (2002). But how do you do that?": Decision making for the seminar facilitator. *Inquiry and the literary text: Constructing discussions in the English classroom/Classroom practices in teaching English, 32*.

Hanson, D. M. (2006). *Instructor's guide to process-oriented guided-inquiry learning*: Pacific Crest Lisle, IL.

Hiebert, J., & Stigler, J. W. (2004). A world of difference. *Journal of Staff Development, 25*(4), 10-15.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235-266.

Hmelo-Silver, C. E., & Barrows, H. S. (2006). Goals and strategies of a problem-based learning facilitator. *Interdisciplinary Journal of Problem-Based Learning, 1*(1), 4.

Hmelo-Silver, C. E., & Eberbach, C. (2012). Learning theories and problem-based learning *Problem-based Learning in Clinical Education* (pp. 3-17): Springer.

Hodson, D. (1987). Social control as a factor in science curriculum change. *International Journal of Science Education, 9*(5), 529-540.

Holland-Cunz, B., & Ruppert, U. (2002). Convention on the elimination of all forms of discrimination against women, New York, 18 December 1979 *Frauenpolitische Chancen globaler Politik* (pp. 91-97): Springer.

Hung, W. (2006). The 3C3R model: A conceptual framework for designing problems in PBL. *Interdisciplinary Journal of Problem-Based Learning, 1*(1), 6.

Hussain, H., & Anwar, N. (2017). Effects of problem based learning on students' critical thinking skills, attitudes towards learning and achievement. *Journal of Educational Research, 20*(2), 28-41.

Jaworski, B. (2007). *Theory in developmental research in mathematics teaching and learning: Social practice theory and community of inquiry as analytical tools.* Paper presented at the Proceedings of the 5th Congress of the European Society for Research in Mathematics Education.

Jimoh, S., & Fatokun, K. (2020). Effect of Problem-Based Learning Strategy on Chemistry Students' Achievement and Interest in Mole Concept in Federal Capital Territory, Abuja. *Anchor University Journal of Science and Technology, 1*(1), 136-143.

Jonassen, D., Spector, M. J., Driscoll, M., Merrill, M. D., van Merrienboer, J., & Driscoll, M. P. (2008). *Handbook of research on educational communications and technology: a project of the association for educational communications and technology*: Routledge.

Jonassen, D. H. (2000). Toward a design theory of problem solving. *Educational technology research and development, 48*(4), 63-85.

Joy, A. (2014). Effect of problem-based learning strategy on students‘ achievement in senior secondary schools chemistry in Enugu State. *IOSR Journal of Research & Method in Education, 4*(3), 27-31.

Kannae, L. (2004). Research skills capacity building for national teachers‘ organization, training manual. *Pan African Teachers Centre, Lome, Togo*.

Kauchak, D. P., & Eggen, P. D. (1993). Learning and teaching. *New York: Allyn Bacon, 2*(3).

Kelly, O. (2005). *The development, implementation and evaluation of alternative approaches to teaching and learning in the chemistry laboratory.* Dublin City University.

Kelly, O. C., & Finlayson, O. E. (2007). Providing solutions through problem-based learning for the undergraduate 1st year chemistry laboratory. *Chemistry Education Research and Practice, 8*(3), 347-361.

Kember, D., & Gow, L. (1994). Orientations to teaching and their effect on the quality of student learning. *The Journal of Higher Education, 65*(1), 58-74.

Kibos, R., Wachanga, S., & Changeiywo, J. (2015). Effects of constructivist teaching approach on students achievement in secondary school Chemistry in Baringo North sub-county, Kenya. *International Journal of Advanced Research, 3*(7), 1037-1049.

Kitto, S. L., & Griffiths, L. G. (2001). The evolution of problem-based learning in a biotechnology course. *The power of problem-based learning. Styles Publ., Sterling, VA*, 121-130.

Krajcik, J. S., Blumenfeld, P. C., Marx, R. W., & Soloway, E. (1994). A collaborative model for helping middle grade science teachers learn project-based instruction. *The Elementary School Journal, 94*(5), 483-497.

Kwon, B.-D., & Kim, K.-J. (2003). An application of Problem Based Learning to an earth science course in higher education. *Journal of the Korean Earth Science Society, 24*(2), 108-116.

Lazear, D. G. (1991). *Seven ways of knowing: Teaching for multiple intelligences: A handbook of techniques for expanding intelligence*: Hawker Brownlow Education.

Levin, B. B. (2001). *Energizing teacher education and professional development with problem-based learning*: ASCD.

Mackenzie, A., Johnstone, A., & Brown, R. (2003). Learning from problem based learning. *University Chemistry Education, 7*(1), 13-24.

Major, C. H., & Palmer, B. (2001). Assessing the effectiveness of problem-based learning in higher education: Lessons from the literature. *Academic exchange quarterly, 5*(1), 4-9.

MaKinster, J. G., Barab, S. A., & Keating, T. M. (2001). Design and implementation of an on-line professional development community: A project-based learning approach in a graduate seminar. *The Electronic Journal for Research in Science & Mathematics Education*.

Matsumura, L. C., Slater, S. C., & Crosson, A. (2008). Classroom climate, rigorous instruction and curriculum, and students' interactions in urban middle schools. *The Elementary School Journal, 108*(4), 293-312.

Matthews, M. R. (2014). *Science teaching: The contribution of history and philosophy of science*: Routledge.

Mayo, P., Donnelly, M. B., Nash, P. P., & Schwartz, R. W. (1993). Student perceptions of tutor effectiveness in a problem- based surgery clerkship. *Teaching and Learning in Medicine: An International Journal, 5*(4), 227-233.

McGrath, D. (2004). Strengthening Collaborative Work: Go beyond the Obvious with Tools for Technology-Enhanced Collaboration. Project-Based Learning. *Learning & Leading with Technology, 31*(5), 30-33.

McInerney, D. M. (2013). *Educational psychology: Constructing learning*: Pearson Higher Education AU.

Mckeachie, W. J. (2007). *Mckeachie Teaching Tips: Strategies, Research, and Theory for College and University Teachers*: Cengage Learning.

McMahon, M. (1997). *Social constructivism and the World Wide Web-A paradigm for learning.* Paper presented at the ASCILITE conference. Perth, Australia.

McMillan, J. H., & Schumacher, S. (2010). Research in Education: Evidence-Based Inquiry, MyEducationLab Series. *Pearson.*

Miles, R. (2015). Tutorial instruction in science education. *Kıbrıslı Eğitim Bilimleri Dergisi, 10*(2), 168-179.

Mills, H. R. (1977). *Teaching and training: A handbook for instructors*: Macmillan International Higher Education.

Mugenda, O. &Mugenda AG (2003), Research Methods: quantitative and Qualitative approaches. *Nairobi: ACTS.*

Muijs, D., & Reynolds, D. (2017). *Effective teaching: Evidence and practice*: Sage.

Nakhleh, M. B. (1993). Are our students conceptual thinkers or algorithmic problem solvers? Identifying conceptual students in general chemistry. *Journal of Chemical Education, 70*(1), 52.

Nechval, N. A., & Nechval, K. N. (2016). Tolerance limits on order statistics in future samples coming from the two-parameter exponential distribution. *American Journal of Theoretical and Applied Statistics, 5*(2-1), 1-6.

Nguyen, N., Williams, J., & Nguyen, T. (2012). *The use of ICT in teaching tertiary physics: Technology and pedagogy.* Paper presented at the Asia-Pacific Forum on Science Learning and Teaching.

Nnorom, N. (2008). *Practical approach to effective teaching of food chain for sustainable development*. STAN Biology Panel Series , 82-85.

Norman, G., & Schmidt, H. G. (1992). The psychological basis of problem-based learning: A review of the evidence. *Academic Medicine, 67*(9), 557-565.

Nwachukwu, A., & Ogbo, A. (2012). The role of entrepreneurship in economic development: The Nigerian perspective. *European Journal of Business and Management, 4*(8), 96.

Nystrand, M. (2006). Research on the role of classroom discourse as it affects reading comprehension. *Research in the Teaching of English*, 392-412.

Okeke, O. J. (2018). Interaction Effect Of Gender And Treatment On Mean Retention Score Of Chemistry Students Taught Using Mend Mapping Teaching Strategy (Mmts) In Enugu. *International Journal of Research in Engineering and Applied Sciences, 8*(*10*), 25-42.

Owusu, F. K. (2020). *Using problem-based learning approach to improve the performance of science students in mole concept, a case study at Techiman Senior High School.* University of Education, Winneba.

Peterson, R. F., & Treagust, D. F. (1998). Learning to teach primary science through problem- based learning. *Science education, 82*(2), 215-237.

Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. *Journal of Engineering Education, 95*(2), 123-138.

Punch, K. F. (2013). *Introduction to social research: Quantitative and qualitative approaches*: sage.

Raimi, S., & Adeoye, F. (2012). Problem based learning strategy and quantitative ability in college of education student's learning of integrated science. *Ilorin Journal of Education, 2*(2), 1-11.

Ram, P. (1999). Problem-based learning in undergraduate instruction. A sophomore chemistry laboratory. *Journal of Chemical Education, 76*(8), 1122.

Reynolds, F. (1997). Studying psychology at degree level: Would problem-based learning enhance students' experiences? *Studies in Higher Education, 22*(3), 263-275.

Reznitskaya, A., Anderson, R., & Kuo, L. (2002). Influence of discussion and explicit instruction on the acquisition and transfer of argumentative knowledge. *Center for the Study of Reading, Champaign, IL*.

Richardson, V. (2003). Constructivist pedagogy. *Teachers college record, 105*(9), 1623-1640.

Rivarola, V. A., & García, M. B. (2000). Problem- based learning in veterinary medicine: protein metabolism. *Biochemical education, 28*(1), 30-31.

Robins, R. W., & Pals, J. L. (2002). Implicit self-theories in the academic domain: Implications for goal orientation, attributions, affect, and self-esteem change. *Self and identity, 1*(4), 313-336.

Rollnick, M., Davidowitz, B., Keane, M., Bapoo, A., & Magadla, L. (2008). Students‘ learning-approach profiles in relation to their university experience and success. *Teaching in Higher Education, 13*(1), 29-42.

Sage, S. M. (1996). A Qualitative Examination of Problem-Based Learning at the K-8 Level: Preliminary Findings.

Sarigoz, O. (2012). Assessment of the high school students‘ critical thinking skills. *Procedia-Social and Behavioral Sciences, 46*, 5315-5319.

Savery, J. R., & Duffy, T. M. (1995). Problem based learning: An instructional model and its constructivist framework. *Educational technology, 35*(5), 31-38.

Savoie, J. M., & Hughes, A. S. (1994). Problem-based learning as classroom solution. *Educational Leadership, 52*(3), 54-57.

Schmidt, H. G., & Moust, J. H. (2000). Factors affecting small-group tutorial learning: A review of research. *Problem-based learning: A research perspective on learning interactions*, 19-52.

Schunk, D. H. (2012). *Learning theories an educational perspective sixth edition*: Pearson.

Science, A. A. f. t. A. o. (1997). Ice Age communities may be earliest known net hunters. *Science, 277*(5330), 1203-1204.

Scott, H. C. (2013). Inquiry, efficacy, and science education.

Şenocak, E. (2005). Probleme dayalı öğrenme yaklaşımının maddenin gaz hali konusunun öğretimine etkisi üzerine bir araştırma. *Unpublished PhD thesis, Atatürk Üniversitesi, Erzurum*.

Senocak, E., Taskesenligil, Y., & Sozbilir, M. (2007). A study on teaching gases to prospective primary science teachers through problem-based learning. *Research in Science Education, 37*(3), 279-290.

Shadreck,M.,& Enunuwe,O.C.(2017). Problem Solving Instructions For Overcoming Students' Difficulties In Stoichiometric Problems. *Acta Didactica Napocensia, 10(4), 69-78.*

Silberman, M. (1996). *Active Learning: 101 Strategies To Teach Any Subject*: ERIC.

Slavin, R. E. (1999). Comprehensive approaches to cooperative learning. *Theory into practice, 38*(2), 74-79.

Song, H.-D., Grabowski, B. L., Koszalka, T. A., & Harkness, W. L. (2006). Patterns of instructional-design factors prompting reflective thinking in middle-school and college level problem-based learning environments. *Instructional Science, 34*(1), 63-87.

Sternberg, R. J. (1998). Abilities are forms of developing expertise. *Educational Researcher, 27*(3), 11-20.

Sungur, S., Tekkaya, C., & Geban, Ö. (2006). Improving achievement through problem-based learning. *Journal of Biological Education, 40*(4), 155-160.

Tarhan, L., & Acar-Sesen, B. (2013). Problem based learning in acids and bases: Learning achievements and students‘ beliefs. *Journal of Baltic Science Education, 12*(5), 565.

Tarhan, L., & Acar, B. (2007). Problem- based learning in an eleventh grade chemistry class:‗factors affecting cell potential‘. *Research in Science & Technological Education, 25*(3), 351-369.

Tarhan, L., Ayar-Kayali, H., Urek, R. O., & Acar, B. (2008). Problem-based learning in 9th grade chemistry class:‗Intermolecular forces‘. *Research in Science Education, 38*(3), 285-300.

Tiwari, A., Lai, P., So, M., & Yuen, K. (2006). A comparison of the effects of problem- based learning and lecturing on the development of students' critical thinking. *Medical Education, 40*(6), 547-554.

Tobin, K. (1986). Student Task Involvement and Achievement in Process-Oriented Science Activities. *Science Education, 70*(1), 61-72.

Torp, L., & Sage, S. (1998). *Problems as possibilities: Problem-based learning for K-12 education*: Ascd.

Torp, L., & Sage, S. (2002). Problem as Possibilities, Problem Based Learning for K-16. *USA: Association for Supervision and Curriculum Development*.

Tretten, R., & Zachariou, P. (1995). Learning about project-based learning: Self-assessment preliminary report of results. *San Rafael, CA: The Autodesk Foundation*, 2014-2015.

Trochim, W. M. (2006). The research methods knowledge base. 2nd. *Edition. Internet WWW page, at URL: http://www. Social research methods. net/kb/(version current as of April 20, 2021)*.

Udousoro, U. (2011). The effects of gender and mathematics ability on academic performance of students in chemistry. *African Research Review, 5*(4).

Umoh, C. (2003). A theoretical analysis of the effects of gender and family education on human resource development. *Journal of curriculum organization of Nigeria, 10*(*1*), 1-4.

Uyeda, S., Madden, J., Brigham, L. A., Luft, J. A., & Washburne, J. (2002). Solving Authentic Science Problems: Problem-based Learning Connects Science to the World Beyond School. *Science Teacher, 69*(1), 24-29.

Valdez, J. E., & Bungihan, M. E. (2019). Problem-based learning approach enhances the problem solving skills in chemistry of high school students. *JOTSE, 9*(3), 282-294.

Van Teijlingen, E. R., Rennie, A.M., Hundley, V., & Graham, W. (2001). The importance of conducting and reporting pilot studies: the example of the Scottish Births survey . *Journal of Advanced Nursing, 3(4), 289-295.*

Vanderstoep, S. W., & Johnson, D. D. (2008). *Research methods for everyday life: Blending qualitative and quantitative approaches* (Vol. 32): John Wiley & Sons.

Von Glasersfeld, E. (1990). An Exposition of Constructivism: Why some like it Radical, Constructivist Views on the teaching and learning of mathematics. *Journal for Research in Mathematics Education Monograph, 4*, 19-29.

Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*: Harvard university press.

Wachanga, S. W., & Mwangi, J. G. (2004). Effects of the cooperative class experiment teaching method on secondary school students' chemistry achievement in Kenya's Nakuru district. *International Education Journal, 5*(1), 26-36.

Weber, K., Maher, C., Powell, A., & Lee, H. S. (2008). Learning opportunities from group discussions: Warrants become the objects of debate. *Educational Studies in Mathematics, 68*(3), 247-261.

Weimer, M. (2002). *Learner-centered teaching: Five key changes to practice*: John Wiley & Sons.

Welman, J., & Kruger, S. (1999). Research Methodology for theBusiness and Administrative Sciences: Cape Town: International Thomson Publishing.

Wertsch, J. V. (1997). Vygotsky and the formation of the mind: Cambridge.

Wickens, T. D., & Keppel, G. (2004). *Design and analysis: A researcher's handbook*: Pearson Prentice-Hall Upper Saddle River, NJ.

Wiersma, W. (1985). *Research methods in education: An introduction*. (No. LB. 1028. W531985).

Wilkerson, L., & Gijselaers, W. H. (1996). *Bringing problem-based learning to higher education: Theory and practice*: Jossey-Bass.

Wong, K. K. H., & Day, J. R. (2009). A comparative study of problem-based and lecture-based learning in junior secondary school science. *Research in Science Education, 39*(5), 625-642.

Wood-Robinson, C., Lewis, J., & Leach, J. (2000). Young peoplea's understanding of the nature of genetic information in the cells of an organism. *Journal of Biological Education, 35*(1), 29-36.

Worgu, B. (1991). Educational research methods: Boston: Houghton Mifflin Company.

Yadav, A., Mayfield, C., Zhou, N., Hambrusch, S., & Korb, J. T. (2014). Computational thinking in elementary and secondary teacher education. *ACM Transactions on Computing Education (TOCE), 14*(1), 1-16.

Ying, Y. (2003). Using problem-based teaching and problem-based learning to improve the teaching of electrochemistry. *The China Papers, 12*(5), 42-47.

Yuzhi, W. (2003). Using problem based learning in teaching analytical chemistry. *The China Papers, 2*, 18-32.

Zikmund, W., Babin, J., Carr, C., & Griffin, M. (2010). Business research methods.. Mason, HO: Cengage Learning.

APPENDIX A

PRE-TEST

STUDENT'S ID [ ]

SECTION I

TIME ALLOWED: 40 MINUTES

From items 1 to 20, each item is followed by four options lettered A to D. Read each statement carefully and circle the letter that corresponds to the correct or best options.

1. Acids taste …..
   a. Sweet b. bitter
   c. Sour d. Salty

2. Bases reacts with
   a. Acids to produce salts and water b. water produces acids and salts
   c. Neither acids, salts nor water. d. Both acid and salt

3. Acids make litmus paper turn
   a. red b. yellow
   c. blue d. dry

4. Which type of solution is one with pH of 8
   a. Acidic b. conjugate
   c. neutral d. basic

5. An electron –pair acceptor is a
   a. Bronsted-Lowry b. Lewis acid
   c. Arrhenius base d. Lewis base

6. What is the $_{p}$H OF 1X10^{-5} M.
   a. 3 b. 5
   c. 9 d. 11

7. What is the correct products for these reactants HCl + NaOH →
   a. HOH + ClNa b. SCl + H_2O
   c. H_3O + $NaCl_2$ d. NaCl + H_2O

8. Strong bases are
   a. Strong electrolyte b. weak electrolyte
   c. nonelectrolyte d. also strong acids

9. A solution with pH of 5.0
   a. is basic b. has a hydrogen-ion concentration of 5.0M
   c. is neutral d. has a hydroxide-ion concentration of $1x10^{-9}$M

10. Which ion do bases contain?
    a. OH- b. H_3O
    c. H+ d. NH4

11. If acidified solution of potassium Dichromate (VI) ($K_2Cr_2O_7$), Dichromate ion ($Cr_2O_7^{-2}$) becomes reduced to :
    a. Chromate (v) ions b. Chromium (III) ions
    c. Chromium (II) ions d. Chromium (V) ions

12. Which of the following is involved in oxidation?
    a. loss of hydrogen b. loss of oxygen
    c. gain in hydrogen d. gain in electrons

13. The total of the oxidation number is an element's
    a. Volality b. charge
    c. reduction d. Oxidation

14. The reduction is a gain of
    a. neutrons b. Protons
    c. electrons d. oxygen

15. Which of the following is not an example of redox reaction?
    a. $CuO + H_2 \rightarrow Cu + H_2{}^{O}$ b. $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
    c. $2K + F_2 \rightarrow 2KF$ d. $BaCl_2 + H_2SO_4 \rightarrow BaSO_4 + 2HCl$

16. The oxidation number of phosphorus in the species HPO_3^{2-} is
    a. +4 b. +5
    c. +3 d. +2

17. Identify the correct statement (s) in relation to the following reaction:
    $Zn + 2HCl \rightarrow ZnCl_2 + H_2$

a. Zinc is acting as an oxidant

b. Chlorine is acting as a reductant

c. zinc is acting as an oxidant

d. hydrogen ion is acting as an oxidant

18. $Sn^{4+} \rightarrow Sn^{2+}$ represents

a. Oxidation

b. reduction

c. hydrolysis

d. none of the above

19. In any oxidation-reduction reaction, the total number of electrons gained is

a. Unrelated to the total number of electrons lost equal
b. less than the total number of electrons lost
c. greater than the total number of electrons lost
d. equal the total number of electrons lost

20. Which of the following is a redox reaction?

a. $2KBr + F_2 \rightarrow 2KF + Br_2$
b. $2HCl + Mg(OH)_2 \rightarrow 2HOH + MgCl_2$
c. $2NaCl + H_2SO_4 \rightarrow Na_2SO_4 + 2HCl$
d. $Ca(OH)_2 + Pb(NO_3)_2 \rightarrow Ca(NO_3)_2 + Pb(OH)_2$

APPENDIX B

POST -TEST

STUDENT'S ID [ ]

SECTION I

TIME ALLOWED: 40 MINUTES

From items 1 to 20, each item is followed by four options lettered A to D. Read each statement carefully and circle the letter that corresponds to the correct or best options.

1. Why is sulfuric acid (H_2SO_4) considered as a Brønsted- Lowry acid?

a. It has a pH greater than 7
b. It is able to donate protons
c. It contains an hydroxide ion
d. it reacts with hydronium ions

2. The compound $Mg(OH)_2$ is classified as an Arrhenius base because, when the compound dissolves in water, there is an increase in the concentration of which of the following ions?

a. Hydrogen ions
b. magnesium ions
c. hydroxonium ions
d. oxide ions

3. The process in which acids (H^+) and bases (OH^-) react to form salts water is called

a. neutralisation
b. hydrogenation
c. halogenation
d. sublimation

4. Which of the following compounds could produce hydroxonium ions in water?

a. calcium hydroxide
b. hydrogen chloride
c. potassium chloride
d. Sodium hydroxide

5. The concentration of the hydroxonium ion in a solution with pOH of 9 is

a. 10^{-5} mol dm^{-3} b. 10^{-7} mol dm^{-3}

c. 10^{-9} mol dm^{-3} d. 10^{-14} mol dm^{-3}

6. A substance which produces the hydroxonium ion as the only positive ion when dissolved in water is

a. an acid b. a base

c. an acid salt d. salt

7. Water is neutral because

a. the concentration of H^+ in water is greater than OH^-

b. the concentration of H^+ in water is equal to that of OH^-

c. the concentration of H^+ in water is less than that of OH^-

d. the concentration of H^+ per dm^3 of water constant

8. An acqueos solution of Na_2CO_3 is

a. alkaline b. acidic

c. amphoteric d. neutral

9. A substance responsible for the sour taste of unripe oranges is

a. alkanol b. alkanoic acid

c. alkanoate d. alkene

10. Weak bases

a. dissociates partially b. ionize completely

c. hydrolyze partially d. oxidize completely

11. The oxidation number of chlorine in in $KClO_3$ is

a. -5 b. -1

c. +1 d. +5

12. Which of the following is **not** oxidizing agent?

a. $KMnO_4$ b. MnO_2

c. O_2 d. H_2S

13. Consider the following redox reaction, what is the value of X ?

$3Mg + xCr^{3+} \rightarrow 3 Mg^{2+} + xCr$

a. 2 b. 3

c. 4 d. 6

14. Potassium is a stronger reducing agent than sodium because potassium

a. has higher atomic number b. has higher electron affinity

c. donates electron more readily d. has greater atomic radius

15. Consider the equation below:

$Cr_2O_7^{2-} + 14H^+ + \square \rightarrow 2Cr^{3+} + 7 H_2O$

How many electrons must replace the box in order to balance the equation?

a. $2e^-$ b. $6e^-$

c. $8e^-$ d. $12e^-$

16. A redox equation is said to be balanced if

a. protons are added to the oxidant

b. electrons are added to the reductant

c. charges and atoms are balanced

d. molecules and neutral atoms are balanced

17. Which of the following reaction is a redox reaction?

a. $Cu_{(s)} + 4HNO_{3\,(g)} \rightarrow Cu(NO_3)_{2\,(g)} + 2NO_{2\,(g)} + 2H_2O_{(l)}$

b. $H_2SO_{4\,(aq)} + CuO_{(s)} \rightarrow CuSO_{4\,(aq)} + H_2O_{(l)}$

c. $H_2SO_{4\,(aq)} + 2NaOH \rightarrow 2Na_2SO_{4(aq)} + 2H_2O_{(l)}$

d. $FeCl_{3(aq)} + 3NaOH \rightarrow Fe(OH)_{3\,(aq)} + 3NaCl_{(aq)}$

18. Which element is reduced in the reaction?

$5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$?

a. hydrogen   b. iron

c. manganese   d. oxygen

19. An oxidizing agent

a. gains electrons   b. loses electron

c. accepts oxygen   c. increase its oxidation number

20. Which of the following processes is reduction?

a. loss of electrons   b. gain electrons

c. gain of electron   d. loss of hydrogen

SECTION II

Q1

(i) Classify each of the following as acidic or basic based on the information provided.

a) Lemon juice tastes sour

…………………………………………………………

b) A dilute solution of potassium hydroxide feels slippery

…………………………………………………………

c) Drain cleaner has a pH of 12

……………………………………………….

d) an aqueous solution Na_2CO_3 of pH 11

…………………………………………………….

Q1.

(ii) Consider the following redox equation

$$Fe^{2+}{}_{(aq)} + Cr_2O_7^{2-}{}_{(aq)} + H^+{}_{(aq)} \rightarrow Cr^{3+}{}_{(aq)} + Fe^{3+}{}_{(aq)} + H_2O$$

Write the half ionic equation for the

(α) oxidation reaction

…………………………………………………………………………………………

…………………………………………………………………………………………

(β) reduction reaction

…………………………………………………………………………………………

…………………………………………………………………………………………

(δ) Write a balanced ionic equation for the overall reaction

………………………………………………………………………………………

…………………………………………………………………………………………….

…………………………………………………………………………………………….

APPENDIX C

PRE TEST (MARKING SCHEME)

SECTION I

1.	C	11.	B
2.	A	12.	A
3.	A	13.	B
4.	D	14.	C
5.	B	15.	D
6.	B	16.	C
7.	D	17.	D
8.	A	18.	B
9.	B	19.	D
10.	A	20.	A

Total = 1×20 = 20 marks

SECTION II

Q1a.

HCl (aq) + NaOH → NaCl (s) + $H_2O_{(l)}$ [3marks]

- HCl – acid [1 mark]
- NaCl – salt [1 mark]
- H_2O - water [1 mark]

Total = 6marks

Q1b.

(α) 0 to +2 [2marks]

(β) +1 to 0 [2 marks]

Total = 4 marks

APPENDIX D

POST TEST (MARKING SCHEME)

SECTION I

1. B	11. D
2. C	12. D
3. A	13. A
4. B	14. C
5. C	15. D
6. A	16. C
7. B	17. A
8. A	18. C
9. B	19. A
10. A	20. C

1×20 = 20 marks

SECTION II

Q1

(i)

a) acidic [**1 mark**]

b) basic [**1 mark**]

c) basic [**1 mark**]

d) basic [**1 mark**]

Q1 (ii)

(α) $Fe^{2+} \rightarrow Fe^{3+} + e^{-}$ oxidation reaction [**2 marks**]

(β) $Cr_2O_7^{2-} + 14 H^{+} + 6e^{-} \rightarrow 2Cr^{3+} + 7 H_2O$ reduction [**2 marks**]

(δ) $6 Fe^{2+} \rightarrow Cr_2O_7^{2-} + 14H^{+} \rightarrow 6 Fe^{3+} + 2Cr^{3+} + 7H_2O$ [**2 marks**]

Total = 10 marks

APPENDIX E

QUESTIONIORE ON STUDENT ATTITUDE TOWARDS PROBLEM-BASED LEARNING

This questionnaire was designed purposely to evaluate your attitude towards the effectiveness of problem-based learning approach used in the teaching and learning of acids, bases and redox reactions. Your identification number is not required and will not be associated with your responses. You are greatly assured of anonymity with your responses. The questionnaire consists of ten items.

Instruction: To each of the following items Please tick **[√]** against each statement that best represents your personal opinion. Against each statement, there are five items

Key: 5= SA= Strongly Agree, 4= A= Agree, 3= N= Neutral, 2= D = Disagree, 1= A= Strongly Disagree

SECTION 1: Questionnaire on Student Attitude towards Problem- Based Learning

Gender: Male [ ] Female [ ]

S/N		SA	A	N	D	SD
		5	4	3	2	1
1.	Problem -based learning requires active stimulation of student participation by the teacher					
2.	The teacher needs to have extensive problem solving knowledge					
3.	Problem-based learning is one of the keys strategies for creating independent thinkers					
4.	The teacher presented a problem that motivated me to learn					
5.	The teacher only act as Facilitator during teaching and learning process					
6.	The Problem-based learning lesson helped me to apply my knowledge to Solve problems.					
7.	The problem-based learning encouraged interaction with other students					
8.	During the problem-based learning I felt as though my opinions were valued					
9.	I have to take more responsibility for Learning in problem-based learning					

10.	Problem-based learning takes up more time than conventional lecture based approach					

APPENDIX F

STUDENTS SELF-LEARNING AND SATISFACTION LEVEL IN THE SELECTED TOPICS IN CHEMISTRY USING PROBLEM-BASED LEARNING APPROACH QUESTIONAIRE

This questionnaire was designed purposely to evaluate your self-learning and satisfaction level in the selected topics in chemistry using problem-based learning approach .Your identification number is not required and will not be associated with your responses. You are greatly assured of anonymity with your responses. The questionnaire consists of 10 items.

Instruction: To each of the following items Please tick **[√]** against each statement that best represents your personal opinion. Against each statement, there are five items

Key: 5= SA= Strongly Agree, 4= A= Agree, 3= N= Neutral, 2= D = Disagree, 1= A= Strongly Disagree

Gender: Male [ ] Female [ ]

S/N		SD 1	D 2	N 3	A 4	SA 5
1.	PBL instructional approach helped to engage and focus my attention on acid, base and redox reaction					
2.	PBL approach has helped me to develop curiosity for what I already know about the selected topics					
3.	PBL has helped me to apply my knowledge and understanding to outline some characteristic properties of acid and bases in aqueous solution					
4.	Through the use of PBL approach I was able to demonstrate knowledge and understanding to describe qualitatively how acid-base indicators work					
5.	PBL approach has enabled me distinguish between solutions that are acidic, neutral or basic using the pH scale					
6.	PBL approach enabled me develop Problem-solving skills relating to pKa and pKb of weak acids and bases					
7.	PBL approach helped me to easily identify oxidizing and reducing agents in any given redox equations					
8.	PBL has helped me to develop numeracy and calculation skills involved in balancing any given redox equations for half-reactions and overall reactions					
9.	Through the use of PBL, I was able extend and apply my knowledge in solving more challenging related acid, base and redox reaction problem					
10.	Through the use of PBL I am confident in my ability to identify and search for information that is needed to solve a problem in other Chemistry topics					

APPENDIX G

EXPERIMENTAL GROUP GENERAL VIEWS ABOUT PROBLEM-BASED LEARNING QUESTIONNAIRE

This questionnaire was designed purposely to evaluate your general views about problem-based learning approach. Your identification number is not required and will not be associated with your responses. You are greatly assured of anonymity with your responses. The questionnaire consists of ten items.

Instruction: To each of the following items Please tick **[√]** against each statement that best represents your personal opinion. Against each statement, there are five items

Key: 5= SA= Strongly Agree, 4= A= Agree, 3= N= Neutral, 2= D = Disagree, 1= A= Strongly Disagree

Gender: Male [ ] Female [ ]

S/N		SA 5	A 4	N 3	D 2	SD 1
1.	PBL approach give one the ability become a critical and analytical thinker					
2.	PBL approach gives the ability to experience different techniques and strategies in solving problems					
3.	PBL help to develop ability to critically accept and analyse others ideas					
4.	PBL help one to seek the appropriate information for the task at hand.					
5.	PBL give one the ability to tackle complex problems					
6.	PBL approach help to improve one's communication skills					
7.	PBL help to stimulate continuous acquisition of new and relevant knowledge					
8.	PBL can be one of the best approach to make teaching and learning of chemistry easier					
9.	PBL approach is better than conventional approaches					
10.	PBL provides opportunity for independent learning and knowledge construction					