UNIVERSITY OF EDUCATION, WINNEBA

EFFECT OF PROBLEM-BASED LEARNING ON STUDENTS' ACHIEVEMENT IN MOLE CONCEPT: A CASE STUDY AT TAMALE COLLEGE OF EDUCATION

BONIFACE YAAYIN

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A THESIS IN THE DEPARTMENT OF SCIENCE EDUCATION, FACULTY OF SCIENCE EDUCATION, SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, UNIVERSITY OF EDUCATION, WINNEBA, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF PHILOSOPHY IN SCIENCE EDUCATION

2016

DECLARATION

Student's Declaration

I, **Boniface Yaayin,** 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.

……………………………   ..……………………

Boniface Yaayin   Date

Supervisor's Declaration

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

……………………………...   ………………………

Dr. J. Nana Annan   Date

(Supervisor)

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I owe a duty to acknowledge the Yaayin's family, my dearest wife and children for all their prayers, support and encouragement. Finally, all my friends including Philip Dorsah and Enoch Nwini, I acknowledge them for their contributions to my work.

DEDICATION

This work is dedicated to my lovely wife Felicia Owusu and my most cherished children Phebe Yaayin and Adeline Yaayin.

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LIST OF ABBREVIATIONS

MCAT: Mole Concept Achievement Test

MCPAS: Mole Concept Perception and Attitude Scale

PBL: Problem-Based Learning

TLB: Traditional Lecture-Based

ABSTRACT

The purpose of the study was to determine the effect of Problem-Based Learning (PBL) on students' achievement in mole concept. The study was quasi-experimental research and nonrandomized control group pre-test – post-test design. The target population consisted of students in the four public Colleges of Education in the Northern Region of Ghana. The accessible population was level hundred students in Tamale College of Education. Purposive sampling was used to obtain a sample of eighty-eight participants from two intact classes for the study. One class was the experimental group and the other the control group because both groups were within the same institution. In the experimental group, the Problem-Based Learning (PBL) approach was used while the Traditional Lecture-Based (TLB) method was used in the control group. The participants (students) were taught the same topic, which is the mole concept by the researcher for a period of four weeks. The instruments used in the study were Mole Concept Achievement Test (MCAT), Likert scale-based questionnaire and interview. The instruments were piloted in another college with similar characteristics and their reliability coefficients were found to be suitable for the study. Data were analysed using t-test, bar charts and percentages. Hypotheses were accepted or rejected at significant level of 0.05. The results of the study reveal that the PBL resulted in significantly higher students' achievement in mole concept compared to the TLB. The students' perception and attitude toward the mole concept was positive with PBL compared to TLB. The results of this study would be beneficial to integrated science and chemistry teachers, curriculum planners and developers as well as policy makers in improving the teaching and learning process and achievement in mole concept.

CHAPTER ONE

INTRODUCTION

1.1 Overview

This chapter contains the background to the study, the statement of the problem, purpose of the study, research objectives and research questions. It also includes the null hypotheses, the significance of the study, limitations and delimitations as well as the operational definition of terms and organization of the report.

1.2 Background to the Study

The level of science education is one of the measures of growth of any nation (Nwachukwu, 2012). Science and technology are said to be the engines of growth and development of every nation. Medicine, engineering, telecommunication, agriculture and pharmacy which are significant indicators for national development all have their roots in the study of science, yet students have difficulties in studying science due to poor foundation and methods of teaching. Many students prefer to study courses in humanities than in sciences. There are normally few students studying science from the senior high school level to the tertiary level. Unfortunately, the numbers keep dropping from the senior high school to the tertiary level. According to Sirhan (2007), chemistry is often regarded as a difficult subject, which sometimes repels learners from continuing with its studies. There are a number of difficult concepts in chemistry such as balancing of chemical equations, redox reactions, nomenclature of hydrocarbons, mole concept and others that pose challenges to students' progress as they study the subject. The role of chemistry as a component of science to national development cannot be overemphasized.

The knowledge of chemistry is greatly needed in all chemical industries in both developed and developing countries, nonetheless, many students continue to drop the subject as they progress with their studies or continue to have difficulties in understanding its concepts as they study it.

The mole concept is still a difficult concept in chemistry for students in the colleges of education in Ghana. Students who do not fully understand the mole concept experience difficulties in understanding subsequent topics such as stoichiometry, chemical equilibrium, acids and bases (Musa, 2009; Taha, Hashim, Ismail, Josoff & Yin, 2014). In science, most of the concepts are interlinked and built on one another. To study one concept, the foundation of another concept would have been laid. If a student fails to understand certain basic or fundamental concepts in a given subject area in science, he/she will encounter difficulties in understanding subsequent concepts in the same subject area. Brown, LeMay, Bursten and Murphy (2009) define a mole as "the amount of matter that contains as many objects (atoms, molecules or whatever objects we are considering) as the number of atoms in exactly 12 g of isotopically pure ^{12}C" (p. 89). The very definition of the mole as a concept is difficult for many students to understand. The terms used in the definition create confusion for some students, thus making it difficult for them to fully comprehend the mole concept. According to Dahsah and Coll (2007), the term carbon-12 atoms, causes some confusion among students owing to the fact that the numerical value (12) of the mass of the carbon atoms looks identical to the value of its molar mass. The mole is a concept because its definition talks about the amount of matter; it is also a unit of measurement because in calculation there can be an expression as ‘0.50 mole’ and finally it is expressed as a number such as one mole is equivalent to the Avogadro’s number (6.02×10^{23}). These expressions of the mole sometimes create confusion in students when they are studying it as a concept.

The traditional lecture-based (TLB) method in teaching science concepts like the mole concept has been the normal practice of many science teachers; nonetheless, many students still have difficulties understanding the mole concept over the years. Hirca (2011) contends that in traditional science lessons, teachers come to teach and students memorise or mimic their acts without understanding and retaining whatever is taught and learnt. This situation leaves many students with no alternative to learning than rote learning where concepts are simply memorized without understanding. The question is whether the teaching method used by a teacher has any influence or reflection on students’ understanding of the subject taught? If the answer is yes, then the choice of a teaching method is very fundamental to assisting students’ understanding of subjects taught in the classroom. Studies have revealed that the teaching method employed by a teacher reflects on students’ understanding of the subject (Akinlaye, 1998; Ifamuyiwa & Ajilogba, 2012). Other researchers also reported that, the teaching method adopted by the teacher in order to promote learning is of topmost importance to enhancing the academic performance of learners (Ajelabi, 1998; Ifamuyiwa & Ajilogba, 2012). According to Njoku (2004), prominent among the contributing factors to students’ persistent poor performance or under achievement in Chemistry include ineffective teaching methods or approaches used by science teachers to teach the subject.

Teaching difficult concepts like the mole concept calls for a teaching strategy or approach that is learner-centred and innovative enough to facilitate learners' interest. According to Hung (2008), problem-based learning (PBL) appears to be the most innovative instructional method conceived and implemented in education with the aim of enhancing students' application of knowledge, problem solving skills, higher-order thinking, and self-directed learning skills. Studies have indicated that problem solving strategies are learner-centred and are capable of making remarkable impact on instructional practices (Ogunyemi, 2010; Ifamuyiwa & Ajilogba, 2012). Problem-based learning is a teaching method characterized by the use of problems (questions) as a contest for students to discuss in a small group to learn problem solving skills and acquire knowledge about the content of concepts whilst the teacher serves as a facilitator. It concentrates actively on generating, adapting and using knowledge to solve problems other than passively acquiring it and making no use of it. Problem-based learning is a total approach of education and involves a constructivist approach to learning (Harper-Marinick, 2001; Atan, Sulaiman & Idrus, 2005). According to Savery (2006), PBL is an instructional approach that has been used successfully for over 30 years and continues to gain acceptance in multiple disciplines.

Considering the usefulness of PBL as a teaching approach as emphasized by researchers on one hand, and the students' difficulties in understanding the mole concept on the other hand, the researcher seeks to find out the effect of problem-based learning on students' achievement in the mole concept in Tamale College of Education.

1.3 Statement of the Problem

First year students offering the general programme in Tamale College of Education have difficulties in understanding the mole concept over the years. This has been observed by the researcher through the teaching of the mole concept and the students' performance in the topic for the past five years. According to the Chief Examiner's Report, Institute of Education, University of Cape Coast (2014), the mole concept is an area where students are not proficient enough.

Studies have shown that students have problems in understanding and utilizing the mole concept in quantitative chemical problems (Bodner & Herron, 2002; Gabel & Sherwood, 2005). To facilitate students' understanding of the mole concept and improve their achievement demand teaching methods that are student-centred and problem- solving where the learner plays an active role in the learning process to own the knowledge acquired and utilize it in solving problems including the mole concept.

1.4 Purpose of the Study

The purpose of the study was to find out the effect of problem-based learning on students' achievement in the mole concept in Tamale College of Education.

1.5 Research Objectives

This study focused on the following objectives:

1. To determine the achievement of the students in the mole concept in the control and experimental groups before the treatment.
2. To compare the achievement of the students in the mole concept using the PBL approach and the TLB method.
3. To find out the students' perceptions and attitudes toward the mole concept using the PBL and the TLB methods.

1.6 Research Questions

This study was guided by the following research questions.

1. What is the difference in achievement of the students in the mole concept in the experimental and control groups before the treatment?
2. What is the difference in achievement of the students in the mole concept using the PBL approach and the TLB method?
3. What are the students' perceptions and attitudes toward the mole concept using the PBL and the TLB methods?

1.7 Null Hypotheses

The following null hypotheses (H_0) were formulated and tested.

H_{01}: There is no significant difference between the achievement of the students in the mole concept in the experimental and control groups before the treatment.

H_{02}: There is no significant difference between the students' achievement in the mole concept using the PBL approach and the TLB method.

H_{03}: There is no significant difference between the students' perception and attitude toward the mole concept using the PBL and the TLB methods.

1.8 Significance of the Study

This study would improve students' understanding of the mole concept in chemistry. It would guide and inform alternative curriculum planning, development and implementation using the PBL approach to teaching and learning other than the traditional lecture-based method. Teachers, particularly science teachers who are at the centre and direct implementers of the curriculum would improve their teaching methodologies using the PBL approach. Knowing the perceptions and the attitudes of students toward the mole concept resulting from the study would inform teachers of their preparations and deliveries of science lessons. It would guide science teachers to demystify certain negative perceptions and attitudes toward the mole concept and study of science in general. The study outcome would also benefit the Ghana Education Service and the Ministry of Education as the PBL approach tackles teaching and learning differently from the traditional lecture-based method.

1.9 Limitations

The research design was quasi-experimental where intact classes were used thus the research participants were not randomly selected and this limited the results of the study to be applied to a larger population. Another limitation was time. The study was conducted over a one month interval of time which depended on conditions available during the time and that could affect the outcome of the study. Again, the ability to fully control all the study variables such as extraneous variables and to determine the implication of the treatment on the study group(s) was limited. It was a limitation to fully prevent the control group from interfering with or seeking information from the experimental group since both groups were within the same institution.

1.10 Delimitations

This study was delimited to only first year general programme students in Tamale College of Education. Additionally, the study involved the students' achievement on some aspects of the mole concept including calculations involving solutions as stated in the revised syllabus for colleges of education in Ghana, but not all areas of the mole concept. The students' achievement on concepts in other parts of their science programme was not studied. Not every first year general programme student was included in the study. The study was delimited to only eight hundred and eighty-eight students as the sample size for the study.

1.11 Operational Definition of Terms

Problem-based learning (PBL): it is a teaching method characterized by the use of problems (questions) as a contest for students to discuss in a small group to learn problem solving skills and acquire knowledge about the content of concepts whilst the teacher serves as a facilitator.

Traditional Lecture-based (TLB): it is a teaching method where the teacher mainly lectures by the use of textbook information to impart knowledge into students such that during the lecture process students do not learn in groups and barely interact with one another to share ideas**.** Students have little opportunity to solve problems while the teaching and learning is in progress, rather, problems may be given as assignment or end of semester examination.

Mole Concept: the mole as a concept is defined as the amount of matter that contains as many objects (atoms, molecules or whatever objects we are considering) as the number of atoms in exactly 12 g of isotopically pure ^{12}C.

1.12 Organisation of the Report

This study was organized into five chapters. Chapter one contained the introduction which comprised the background to the study, the statement of the problem, the purpose of study, research objectives, research questions, null hypotheses, significance of the study, limitations and delimitations, operational definitions of terms as well as the layout of the report. Chapter two addressed the literature review of the study in the following areas; conceptual framework, theoretical framework, empirical framework and summary of the reviewed literature.

Chapter three centred on the research methodology which constituted the research design, population, sample and sampling procedure, study area, research instruments, methods of data collection and data analysis. The results and discussion were presented in chapter four and the summary of findings, conclusions and recommendations were addressed in chapter five.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

Literature is reviewed under the following: the conceptual framework which includes concept of the mole and amount of substance and concept of problem-based learning. It also covers features of problem-based learning which considers learners' role in problem-based learning, teachers' role in problem-based learning, assessment in problem-based learning and tutorial in problem-based learning.

The theoretical framework which is based on the constructivist theory in relation to problem-based learning was reviewed. The empirical review in line with the research questions was based on effect of PBL and TLB on students' achievement in the mole concept and the students' perception and attitude toward the mole concept.

2.2 Conceptual Framework

According to Imenda (2014), a conceptual framework is understood to be an end result of bringing together a number of related concepts to explain or predict a given event, or give a broader understanding of the phenomenon of interest or simply, of a research problem. Under this framework, the following concepts were reviewed; concept of the mole and amount of substance, concept of problem-based learning, features of problem-based learning, learners' role in problem-based learning, teachers' role in problem-based learning, assessment in problem-based learning and tutorial in problem-based learning

2.2.1 Concept of the mole and amount of substance

Furio, Azcona, Guisasola and Ratcliffe (2000), posit that the mole concept was introduced by Ostwald at the beginning of the 20th century, with a meaning of weight (mass), in a context of skepticism towards Dalton's atomic hypothesis. The study further emphasises that historically, the mole concept was introduced before the quantity 'amount of substance' for which it is the unit. The study therefore contends that this, together with the evolution undergone by its meaning, accounts for the controversy in these concepts. According to the study when referring to the quantity 'amount of substance' as that serving to count elementary entities, the indication is what it is used for. The operative definitions are expressed through the relations to mass, to volume or to the number of elementary entities: $n = m/M$; $n = V/V_m$; $n = N/N_A$ where the connections of '*n*' with '*m*', '*V*' or 'N_A' are established (where *M* is the molar mass, *Vm* the molar volume, *NA* the Avogadro constant, *'n'* is the amount of substance, *'m'* is the mass, *'V'* is the volume and *'N'* is the elementary entities).

A study by Staver and Lumpe (1995) that sought to investigate the understanding of the mole concept by secondary students, reveal that some students identified the mole with number of particles, while others identified it with mass in grams, even though the mole concept had been defined according to the International System. The study further points out that the students have the following two deficiencies: (a) incapacity to transfer meaning between the concrete/macro level and the (sub) micro (atomic/molecular) level when solving problems; and (b) insufficient understanding of the concepts and rote use of algorithms and rules. The confusion created was that the students have the idea that the gram and the unit of atomic mass are equivalent. According to Case and Fraser (1999), students have acute difficulties in dealing with the abstract concepts required of them to perform stoichiometric calculations using the mole concept. The study also finds that for students to solve stoichiometric problems, a thorough understanding of the principles involved in mole ratio and proportion calculations should be applied.

2.2.2 Concept of problem-based learning

De Graaff and Kolmos (2003) claim that problem-based learning (PBL) is widely regarded as a successful and innovative method for engineering education. According to them, since the development of the PBL model at McMaster University in Canada in the late 1960s, many different varieties have emerged. They further assert that PBL is an educational approach whereby the problem is the starting point of the learning process.

Further explanation of the concept by Savery (2006) noted that problem-based learning is an instructional learner-centered rather than teacher-centred approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a practical solution to a defined problem. In this case learners become the centre of the teaching and learning process with the empowerment to devising practical solutions to problems they encounter. According to Hmelo-Silver and Barrows (2006), in PBL, students have the opportunity to develop skills in reasoning and self-directed learning. Finlayson and Kelly (2007) explained that PBL sees a shift in educational focus from a teacher-centred approach to teaching and learning to a student-centred one, where students construct meaning for themselves by relating new concepts and ideas to previous knowledge.

2.2.3 Features of problem-based learning

White (2001) argues that the content and structure of PBL courses may differ, however, the general goals and learning objectives tend to be similar. According to Newman (2005), the key features of problem-based learning include the following; learning in small groups, teacher as facilitator, appropriate assessment, tutorial process to stimulate reflection, active participation and application as well as use of 'problems' to stimulate or motivate, contextualize and integrate learning. This suggests that problem-based learning is a broad instructional method that embodies different features to clearly explain its concept. Each of the features plays an important role to determining the overall outcome of the PBL as an instructional method.

In re-emphasising the features of PBL, Barrows (1996) points out that PBL has the following characteristics; learning is student-centered, authentic problems form the focus for learning, new information is acquired through self-directed learning, learning occurs in small groups and teachers act as facilitators.

2.2.4 Learners' role in problem-based learning

Beyond self-directed learning, PBL requires students to be active and that students who are actively engaged in the educational process make substantive connections with course content. These connections promote a deep level of processing in learning (Knowlton, 2003). The study further posits that through collaborative learning and social interaction, students can help shape each other's ideas by providing feedback to each other. As students receive feedback, they can effectively refine their ideas in light of that feedback and submit their newly shaped and refined thoughts to classmates for further debate and discussion.

Murphy, Mahoney, Chen, Mendoza-Diaz and Yang (2005) in line with collaborative learning also assert that a collaborative learning environment, as opposed to a passive learning environment, helps students learn more actively and effectively. Learning under PBL is more of groups than individual approach. According to Burke (2011), learning in groups comes with the following advantages:

- Groups have more information than a single individual. Groups have a greater resources to tap and more information available because of the variety of backgrounds and experiences among group members
- Groups stimulate creativity.
- People remember group discussions better. Group learning fosters learning and comprehension.
- Decisions that students help make yield greater satisfaction.
- Students gain a better understanding of themselves. Group work allows people to gain a more accurate picture of how others see them.
- Team work is highly valued by employers (p. 88).

Gayatan and McEwen as cited in Chiong and Jovanovic (2012) in contribution to the importance of learning in small groups, note that small groups enable students to identify and correct misconceptions more easily and quickly, and to improve understanding of the topics being studied. There is a well of information about group work and the benefits of collaborative learning. When students spend time meeting in groups, they are able to achieve a deeper learning themes covered in class as well as develop skills, such as writing and communication (Light, 2001; Burke, 2011).

2.2.5 Teachers' role in problem-based learning

In PBL, the teacher's role is to facilitate collaborative knowledge construction (Hmelo-Silver & Barrows, 2006). That is to say knowledge construction is not the sole responsibility of the teacher, but to facilitate the learners to construct their own knowledge. The study further intimates that in PBL, a teacher is a facilitator of student learning, and the interventions of the teacher diminish as students progressively take on responsibility for their own learning processes.

In the light of the teacher being seen as a facilitator of process of learning, Harden and Crosby (2000), opine that, the teacher is both a mentor and a learning facilitator. The teacher serves as a mentor, personal adviser or tutor to a student or group of students. As a learning facilitator, the teacher supports students' learning in problem-based learning small groups in the laboratory and in the integrated practical class sessions. The studies additionally explain that the move to a more student-centred view of learning required a fundamental shift in the role of the teacher. No longer is the teacher seen predominantly as a dispenser of information or walking tape recorder, but rather as a facilitator or manager of the students' learning. The more responsibility and freedom given to the student, the greater the shift required in the teachers' role.

2.2.6 Assessment in problem-based learning

O'Grady (2004) addresses the issues of assessment in problem based learning by pointing out that assessment encompasses measuring, defining and summarizing what students can do and/or inferring what students could do. According to O'Grady (2004), student assessments (assignments, examinations, presentations, portfolios etc) are widely accepted as an important part of the learning process. He further notes that PBL offers an alternative approach to learning where assessment is an integral element in both the facilitation and measurement of understanding. Assessment has for a long time been recognised as a powerful driver of learning, and therefore something that teachers could leverage on to ensure students achieve desired objectives.

According to De Graaff and Kolmos (2003), in PBL, the assessment methods must be compatible with the objectives of the learning process. The learning process in PBL is about the students constructing their own knowledge while the teacher serves as a facilitator, thus in the learning process students tend to assess their learning progress. Moursund (1999) reveals that as students are responsible for their own learning in PBL setting, students learn self-reflection and become proficient in assessing their own progression in learning and also peer-assessment on how to effectively provide constructive feedback to their peers.

2.2.7 Tutorial in problem-based learning

Students show positive attitude change as they become more active and motivated in the learning process (Leow & Neo, 2014). Regarding the need to offer some level of tutorial to stimulate learning, Park (2003) observes that students who actively engage with what they are studying tend to understand more, learn more, remember more, enjoy it more and be more able to appreciate the relevance of what they have learned, than students who passively receive what the teachers teach them. Teachers are therefore presented with a huge challenge, which is how to encourage and enable students to engage in the learning process. According to Dolmans, Gijselaers, Moust, De Grave, Wolfhagen and Van Der Vleuten (2002), in PBL, teachers do not primarily disseminate information to students, but teach students to find answers to their own questions, facilitate students' learning process and provide students with feedback. The study argues that PBL tutoring emphasizes the importance of student-centred instead of teacher-centred education. A tutor should encourage specific kinds of cognitive activities, such as making connections, providing feedback and helping students to monitor their own learning.

Kuiper and Pesut (2004) also posit that in a PBL course, learning is structured around a realistic case scenario that provides context to facilitate reflection and critical thinking on the part of the learners who are expected to provide feedback on what they have been guided to learn. The feedback component of a PBL course promotes students' reflections on their actions and facilitates development of strategies for improved performance (Williams, 2001). In PBL, students work in small tutorial groups on problems and in the process, formulate goals for self-directed learning. The adapted conceptual framework for the study is presented below (Kibos, Wachanga & Changeiywo, 2015) (Figure 2.1).

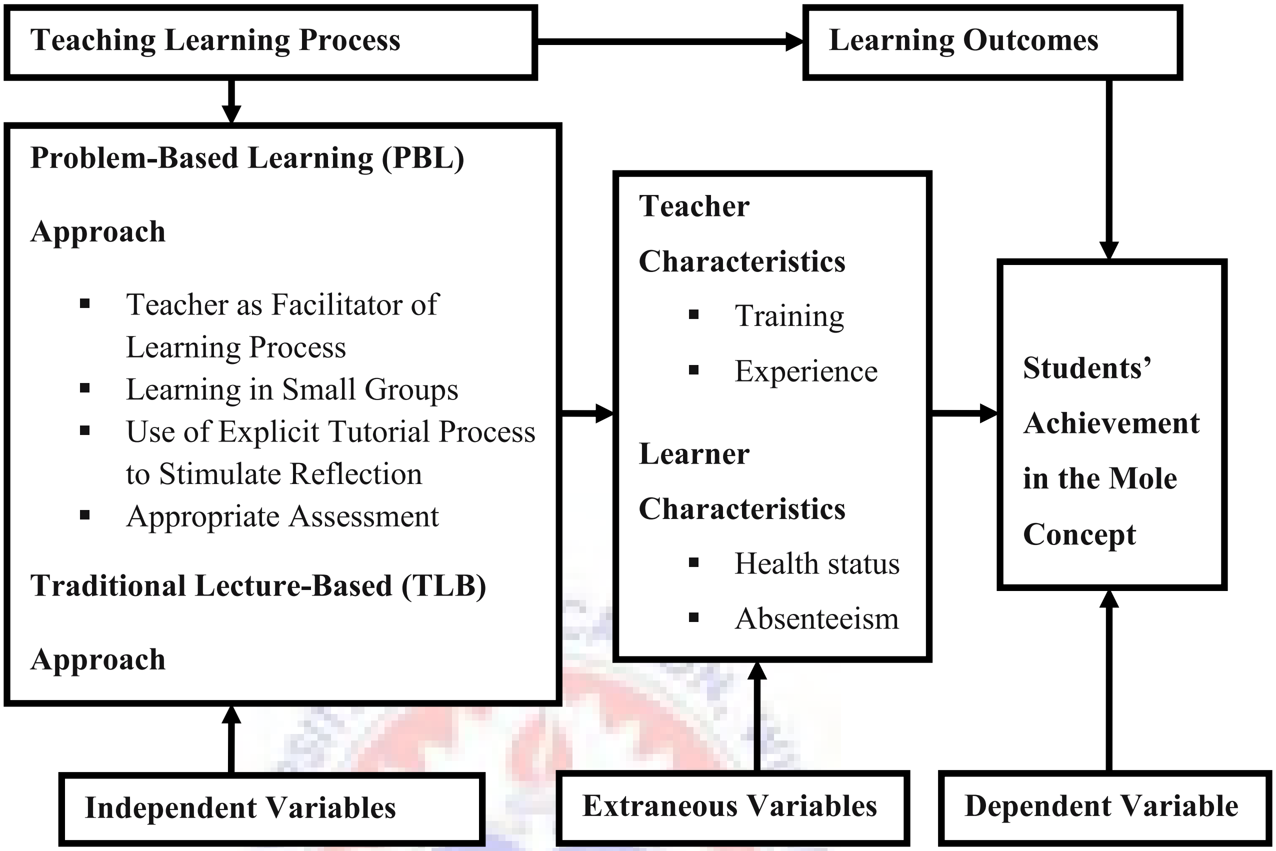

Fig. 2. 1: Conceptual Framework for Determining the Effect of Problem-Based Learning on Mole Concept

2.3 Theoretical Framework

A theoretical framework is the application of a theory, or a set of concepts drawn from one and the same theory, to give an explanation of an event, or throw some light on a particular phenomenon or research problem (Imenda, 2014). The theoretical framework for this study is based on the constructivist theory. According to Taber (2011), constructivism is a major referent in education, though it has been understood in various ways, together with as a learning theory; a philosophical stance on human knowledge; and an approach to social enquiry. Constructivism is a theory of learning which was developed in the recent years and has become the significant and dominant perspective in science education (Taber, 2006).

The origins of constructivism are believed to date back to the time of Socrates, who maintained that teachers and learners should talk with one another, interpret and construct the hidden knowledge by asking questions (Hilav, cited in Erdem, 2001). Lutz and Huitt (2004) believe that, the developmental theories of Dewey, Piaget, Vygotsky, and Bruner provide the basis for the educational application of constructivism. Social constructivism, strongly influenced by Vygotsky's (1978) work, suggests that knowledge is first constructed in a social context and is then internalized and used by individuals.

According to Amineh and Als (2015), although the roots of constructivism are most often attributed to the work of Jean Piaget, constructivist tenets emerged much earlier in history as seen in the writings of Giambattista Vico, who declared in 1710, “The human mind can know only what the human mind has made” (von Glasersfeld, 1995, P.21). Although Piaget's theories tended to focus primarily on the development of the individual while ignoring the greater socio-cultural context, the roots of constructivism are clearly present in Piaget's focus on the active role of the individual in learning: “… all knowledge is tied to action, and knowing an object or an event is to use it by assimilating it to an action scheme…” (Piaget, pp. 14-15, cited in Jones & Brader-Araje, 2002). For Piaget, knowledge construction takes place when new knowledge is actively assimilated and accommodated into existing knowledge.

On the subject of constructivism, some scholars observe that in constructivism, teachers and peers support and contribute to learning through the concepts of scaffolding, cognitive apprenticeship, tutoring, and cooperative learning and learning communities (Brown & Rogoff, cited in Amineh & Als, 2015). Constructivism has been explained in the following ways: "constructivism is not a theory about teaching … it is a theory about knowledge and learning… the theory defines knowledge as temporary, developmental, socially and culturally mediated, and thus, non-objective" (Brooks & Brooks, p. vii, cited in Jones & Brader-Araje, 2002).

> It is assumed that learners have to construct their own knowledge - individually and collectively. Each learner has a tool kit of concepts and skills with which he or she must construct knowledge to solve problems presented by the environment. The role of the community - other learners and teacher - is to provide the setting, pose the challenges, and offer the support that will encourage mathematical construction as cited in (Davis, Maher & Noddings, p. 3, cited in Jones & Brader-Araje, 2002).

"The central principles of this approach are that learners can only make sense of new situations in terms of their existing understanding. Learning involves an active process in which learners construct meaning by linking new ideas with their existing knowledge" (Naylor & Keogh, p.93, cited in Jones & Brader-Araje, 2002).

Lutz and Huitt (2004) account that the work of Dewey, Piaget, Vygotsky, and Bruner presents a strong case that claims that human beings seek meaningful interactions with the environment and construct knowledge of themselves and the world around them through these interactions. Collectively, these theorists provide the foundation for an approach to learning called constructivism as cited in (Lutz & Huitt, 2004). According to Taber (2011), within science education, constructivism has been considered as the accepted paradigm for thinking about learning, as a well-established principle now widely taken for granted, and as a philosophically dangerous tendency that undermines science through relativism.

The core ideas on constructivism and learning, partly based on the analysis of Taber are indicated as:

> Knowledge is actively constructed by the learner, not passively received from the outside. Learning is something done by the learner, not something that is imposed on the learner. Learners come to the learning situation (in science) with existing ideas about many phenomena. Some of these ideas are ad hoc and unstable; others are more deeply rooted and well developed. Learners have their own individual ideas about the world, but there are also many similarities and common patterns in their ideas. Some of these ideas are socially and culturally accepted and shared, and they are often part of the language, supported by metaphors etc. These ideas are often at odds with accepted scientific ideas, and some of them may be persistent and hard to change. Knowledge is represented in the brain as conceptual structures, and it is possible to model and describe these in some detail. Teaching has to take the learner's existing ideas seriously if they want to change or challenge these. Although knowledge in one sense is personal and individual, the learners construct their knowledge through their interaction with the physical world, collaboratively in social settings and in a cultural and linguistic environment (Taber, cited in Baker, McGaw, & Peterson, 2007, p.3).

According to Kibos, Wachanga and Changeiywo (2015), in the constructivist classroom, the teachers' role is to organize situations which will allow the learners to hypothesize, predict, manipulate objects, pose questions, research, investigate and invent meanings. A constructivist classroom is student centered placing more value on student learning rather than the teacher teaching. As a learner-centred method that challenges the learner to take a progressively increasing responsibility for his or her own learning, PBL is therefore consistent with the constructivist theory (Coombs & Elden, 2004).

2.4 Effect of PBL and TLB on Students' Achievement in the Mole Concept

Problem-solving is a prominent feature in the learning of science and its neglect could have negative effect on students' learning outcome in the sciences (West, 1992; Orji, 1998; Adeoye, 2000). According to Shehu (2015), a study conducted on the effect of problem-solving instructional strategies on students' learning outcomes in senior secondary school chemistry, the results show that student taught using problem-solving performed significantly better than those taught through lecture method in improving students' achievement in the mole concept. Kehinde (2005) also supports the idea that students taught using the problem-solving approach performed significantly better than those taught using the lecture method approach. In recent times, there is a complete shift from the 'chalk and talk' method of teaching to learner-centred method of teaching. The traditional lecture-based approach is increasingly becoming less effective as argued by researchers. Alternatively, problem-based learning as one of the instructional strategies is fast gaining ground as it has proven to be an effective teaching method that improves learners' performance.

Problem-solving is the highest form of learning (Babatunde, 2008). Studies have shown that topics in chemistry that are mathematically inclined are intellectually demanding. Ayodele (2011) reveals that certain concepts such as the mole concept, chemical reactions and others require adequate knowledge of basic mathematical concepts in order to cope with them, the factor which probably makes chemistry one of the most intellectually demanding subjects. It therefore suffices to indicate that the mole concept which has been mentioned to be one of the difficult topics in chemistry cannot be effectively taught by the traditional lecture-based approach. It will require a learner-centred approach like PBL to effectively handle such topics in chemistry.

According to Furio, Azcona and Guisasola (2002), students have significant difficulties in handling the concepts 'amount of substance' and 'mole' in addition, they hardly use strategies based on the calculation of amounts of substance when they solve problems. The study noted that the problem of lack of understanding of the concepts 'amount of substance' and 'mole' noticeable by students is strongly related to teachers' ideas and to the methodologies used in the teaching of chemistry. Students generally fear science topics that are mathematically inclined. Topics that involve calculations are usually not friendly to them. In this regard, one of the ways forward is to stick to teaching methods that will motivate the learners to learn. A teaching method that will constantly put students in the centre of the learning by ensuring their active engagement in the learning process is required.

Shehu (2015) opines that problem-solving is a prominent feature in the learning of science and its neglect could have negative effect on students' learning outcome in science. This certainly with no doubt has made science enterprise more problems based in comparison with other fields of human endeavour. According to him, problem-solving has been an aspect of chemistry teaching and learning that has attracted the attention of chemical educators. According to Danjuma (2011), chemists function best in problem-solving. Problem-solving has long been identified as a skill that promotes a better understanding of scientific and mathematics concept.

Raimi and Adeoye (2004) contend that the superiority of problem based learning strategy over the conventional method could be attributed to the logical and sequential manner with which instructions are presented in problem based technique and practical skills teaching. According to Fatoke and Olaoluwa (2014), the conventional lecture method of teaching chemistry proved less effective than the problem-solving method. In addition, the incorporation of problem-solving into chemistry learning improves the performance as well as the attitude of students with high ability than their counterparts with low ability. They argue that if problem-solving instructional strategy could improve students' learning outcomes in chemistry, it would be necessary to overhaul the mode of instruction of teaching chemistry so as to accommodate functional student- centred and activity- oriented instructional strategy that will make chemistry students good problem-solvers, thereby causing improvement in the performance of students in Schools.

Akar (2005) finds that the constructivist approach to teaching enables students to perform better in chemistry achievement test than the traditional lecture method. This is because the students in the constructivist group have the opportunity to benefit from discussion and interaction with peers than the traditional lecture method. According to Kibos, Wachanga and Changeiywo (2015), instructions based on the constructivist teaching approach caused a significantly better students' achievement in chemistry than the conventional teaching methods.

2.5 Students' Perception and Attitude toward the Mole Concept

According to Pedretti (2010), a study on the effects of inquiry-based activities on attitudes and conceptual understanding of stoichiometric problem-solving in high school chemistry reveals that the students' attitudes toward mole calculations improved after using an inquiry-based activity. Uzuntiryaki and Geban (2004) also conducted a study on the effectiveness of instruction based on constructivist approach on students' understanding of chemical bonding and the results of the study indicated that students instructed by the constructivist approach had more positive attitudes toward chemistry as a school subject than students taught by the traditionally designed chemistry instruction. The study equally concluded that most students view chemistry as a difficult subject to learn and they try to avoid chemistry instruction in schools.

According to Erifyli and Georgios (2000), the superiority of the constructivist method of teaching to the traditional method could be attributed to the active participation of students in all processes of learning. This develops a positive attitude of students towards chemistry, and consequently results in higher achievement. On the other hand, they claim that the passive role that the receptive, teacher-centred method reserves for students leads to many of them experiencing boredom, decrease in interest and develop a negative attitude towards chemistry, thus resulting in lower achievement. This suggests that the choice of the teaching method can go a long way to influence the attitudes of learners toward a given subject. The instance where a particular subject or topic is conceived difficult, the choice of the teaching method can either bring about a positive attitude or negative attitude of learners toward it. In another study, Fatoke and Olaoluwa (2014) presented the findings which reveal that problem-solving instructional strategy influences students' attitude towards chemistry learning based on gender. That is the attitude of male and female students towards chemistry learning differs for the problem-solving (experimental) and controls groups.

Chepkorir (2013) asserts that students themselves contribute to their own failure in Chemistry. Negative attitudes, lack of interest and lack of confidence are all contributing factors. The study argues that some of the causes of students' negative attitudes towards learning chemistry include wide coverage of syllabus, low awareness of career opportunities in the subject, lack of exposure to well-equipped laboratory as well as poor teaching methods. According to Chambers (2004), the norms and values of a particular peer group make a difference to the school attainment and involvement of students. This implies a student whose friends work hard is likely to work hard as well. Factors contributing to students' persistent poor performance or under achievement in chemistry include gender stereotyping, poor attitudes towards the subject and low numerical ability (Ubom, 2003; Okeke, 2003).

According to Mulford and Robinson (2002), the students' self-developed concepts do not match up with the scientific theories. Students have their own misconceptions about certain concepts in science that do not reflect the real scientific theories about those concepts, thus influencing their perceptions and attitudes toward those concepts. Larson (1997) argues that students may fail to construct meaningful understandings of the mole concept for the following reasons: inconsistency between the instructional approaches of the textbook and teacher, confusing mole concept vocabulary, students' mathematical anxiety, learners' cognitive levels, and lack of practice in problem solving. The study further contends that due to its abstract, theoretical nature, the mole concept has been recognized as one of the most difficult topics to teach and learn within the chemistry curriculum. According to Polancos (2009), the mole concept is an area that very few students like and succeed at, and which most students hate and struggle with because they find mathematics difficult.

2.6 Summary of Related Literature

The related literature focused the conceptual framework, the theoretical framework and the empirical review. The conceptual framework highlighted the mole as a concept, concept of problem-based learning and features of problem-based learning. The features were limited to learners' role in problem-based learning, teachers' role in problem-based learning, assessment in problem-based learning and tutorial in problem-based learning.

The theoretical framework centred on the constructivist theory in relation to problem-based learning. The empirical review was limited to the research questions comprising the effect of problem-based learning and traditional lecture-based on students' achievement in the mole concept and students' perceptions and attitudes toward the mole concept.

According to Furio, Azcona, Guisasola and Ratcliffe (2000), the mole concept was introduced by Ostwald at the beginning of the 20th century, with a meaning of weight (mass), in a context of skepticism towards Dalton's atomic hypothesis. Historically, the mole concept was introduced before the quantity 'amount of substance' for which it is the unit. The operative definitions are expressed through the relations to mass, to volume or to the number of elementary entities. On the concept of problem-based learning, the reviewed literature revealed that problem-based learning (PBL) is widely regarded as a successful and innovative method for engineering education and that the PBL model was developed at McMaster University in Canada in the late 1960s with many different varieties emerging (De Graaff and Kolmos, 2003). The concept of PBL maintains that the problem is the starting point of the learning process, learner-centred rather than teacher-centred approach to teaching (De Graaff & Kolmos, 2003; Savery, 2006). Per the concept, learning is self-directed where students construct meaning for themselves by relating new concepts and ideas to previous knowledge (Hmelo-Silver & Barrows, 2006; Finlayson & Kelly, 2007). On the subject of the features of PBL, per the learners' role, they are said to be actively engaged in the learning process, provide feedback to one another as they engage in small group discussion. Small groups learning comes with advantages that promote creativity among learners, foster learning and comprehension as well as increase retention of whatever that is learned (Knowlton, 2003; Burke, 2011). The teacher's major role is to facilitate collaborative knowledge construction and serves as a mentor in a mentor-mentee relationship with the learners (Harden & Crosby, 2000; Hmelo-Silver & Barrow, 2006).

The theoretical framework for this study is based on the constructivist theory which holds that the developmental theories of Dewey, Piaget, Vygotsky, and Bruner provide the basis for the educational application of constructivism (Lutz & Huitt, 2004). Knowledge is first constructed in a social context and is then internalized and used by individuals (Vygotsky, 1978). Knowledge construction takes place when new knowledge is actively assimilated and accommodated into existing knowledge. In the constructivist classroom, the teachers' role is to organize situations which will allow the learners to hypothesize, predict, manipulate objects, pose questions, research, investigate and invent meanings, hence PBL is consistent with the constructivist theory (Coombs & Elden, 2004; Kibos, Wachanga & Changeiywo, 2015).

Last but not least, the empirical review on the effect of PBL and TLB on students' achievement in the mole concept reveals that instructions based on the constructivist teaching approach (PBL and others) cause a significantly better students' achievement in chemistry than the conventional teaching methods or traditional lecture-based (Raimi & Adeoye, 2004; Akar, 2005; Kehinde, 2005; Fatoke & Olaoluwa, 2014). Studies equally admitted that the mole concept is a difficult area to study and intellectually demanding and for that matter chemistry in general (Furio, Azcona & Guisasola, 2002; Ayodele, 2011). Regarding the perception and attitude of students toward the mole concept, studies reveal that students attitude toward the mole concept and chemistry in general improves when taught with the constructivist approach to teaching (Erifyli & Georgios, 2000; Uzuntiryaki & Geban, 2004; Pedretti, 2010; Fatoke & Olaoluwa, 2014). It has also been established that students do show negative attitude toward the mole concept and chemistry in general owing to the difficult nature of the concept and the mathematical nature of it (Larson, 1997; Okeke, 2003; Ubom, 2003; Polancos, 2009; Chepkorir, 2013). Below is the framework that summarizes the related literature (Figure 2.2).

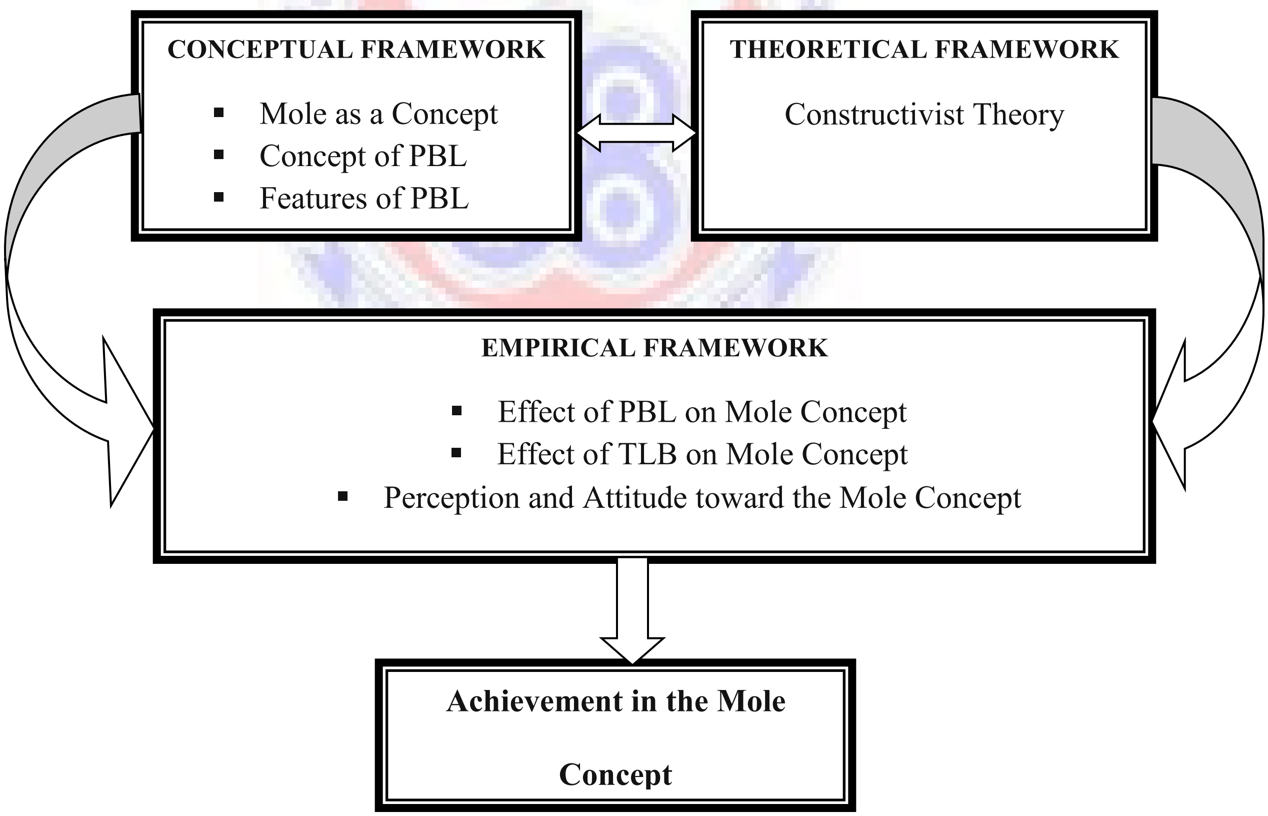

Fig. 2.2: Framework that Summarizes the Related Literature

CHAPTER THREE

METHODOLOGY

3. 1 Overview

This chapter contains the research design, the population as well as sample and sampling procedure. It also comprises the research instruments, the description of the instruments including the reliability and validity of the main instrument. The chapter ends with the methods of data collection and data analysis.

3.2 Research Design

Garg and Kothari (2014) state “a research design is the conceptual structure within which research is conducted and that it constitutes the blueprint for the collection, measurement and analysis of data” (p. 29). The quasi-experimental design was used for the study. Levy and Ellis (2011) posit that the quasi-experiment is a type of experimental design in which the researcher has limited leverage and control over the selection of samples. In quasi-experiments, the researcher does not have the ability to randomly assign the samples and ensure that the sample selected is as homogeneous as desirable thus limiting the selection of research samples to non-randomisation process where study groups are already organized into classes. Ary, Jacobs and Razavieh (2002) state “in a typical school situation, schedules cannot be disrupted nor classes reorganized to accommodate a research study, in such a case it is necessary to use groups as they are already organized into classes or other preexisting intact groups” (p. 316).

Despite the limitations of quasi-experiments, researches reveal that quasi-experiments still provide fruitful information for the advancement of research (Leedy & Ormrod, 2010; Levy & Ellis, 2011). This design has advantages over others since it controls the major threats to internal validity except those associated with interaction of selection and history, selection and maturation and selection and instrumentation (Cook & Campbell, cited in Kibos, Wachanga & Changeiywo, 2015). Quasi-experimental studies can inform discussions of cause and effect, but, unlike true experiments, they cannot definitively establish this link.

A nonrandomized control group, pre-test - post-test design was used for the study. The nonrandomized control group, pre-test - post-test design is indicated below (Figure 3.1).

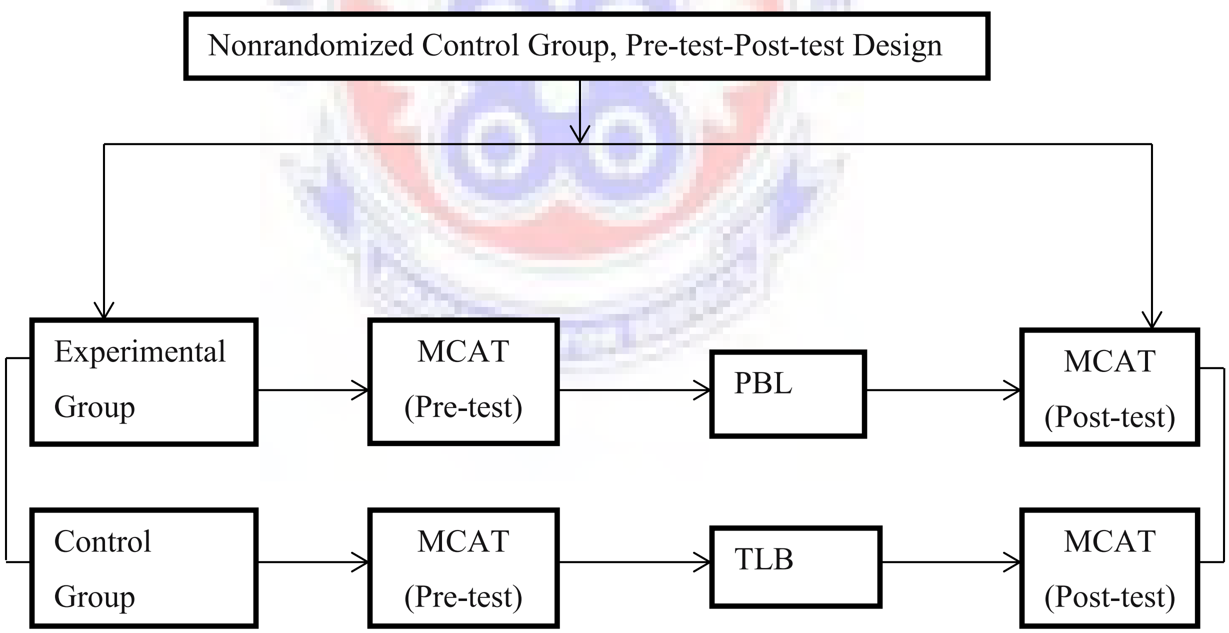

Fig. 3.1: Nonrandomized Control Group Pre-test-Post-test Design (Ary, Jacobs & Razavieh, 2002)

The experimental group was the group taught with the PBL which is an independent variable and the control group was the group taught with the TLB which is also an independent variable. Before both groups were taught with the PBL and the TLB approaches, each received the Mole Concept Achievement Test (MCAT) in the form of pre-test which is a dependent variable. The MCAT in the form of post-test which is also a dependent variable was administered on both the experimental and control groups after they were taught with the PBL and TLB approaches (Figure 3.1).

3.3 Population

The target population consisted of all the students in the four public Colleges of Education in the Northern Region of Ghana. The accessible population however constituted all first year students of Tamale College of Education. This college was purposively chosen because the researcher is a tutor in the college hence it was easier to conduct the research there. The researcher is familiar with already organised intact classes for the study. The needed resources such as the classrooms, teaching and learning materials and the cooperation of the school authorities were not obstacles to the study since the researcher is already a staff of the college.

3.4 Sample and Sampling Procedure

The primary purpose of research is to discover principles that have universal application, but to study a whole population to arrive at generalizations would be impracticable, if not impossible due to availability of resources and errors in the process (Best & Kahn, 1995). To avoid these shortcomings in using populations for research, it is appropriate to select samples from the population. Adding to the reasons raised by Best and Kahn (1995) as to studying a whole population may not be appropriate, Fraenkel and Wallen (2003) assert that one of the most important steps in the research process is to select the sample of individuals who will participate as part of the study rather than using a whole population which may be too large to study.

Purposive sampling technique was used to select the sample for the study. Teddlie and Yu (2007) define purposive sampling technique as "selecting units (individuals, groups of individuals, institutions, etc) based on specific purposes associated with answering a research study's questions" (p. 77). The sample selection was purposive because the research participants were already in intact classes. The participants selected for the study were eighty-eight first year students of Tamale College of Education who were offering Diploma in Basic Education (General Programme) where integrated science containing the mole concept was taught. First year students who were offering pure science programme were not included in the study because integrated science was not part of their syllabus. Two intact classes (1 A and 1 K), each with forty-four first year students (twenty-two males and twenty-two females) were purposively chosen for the study. The consent of the research participants was sought before they were included in the study.

3.4.1. Small groups' formation

The PBL approach requires formation of small groups within the experimental group for the study. Even though the research participants for the experimental group were forty-four by purposive sampling, the small groups' formation demands some sampling techniques. Stratified random sampling technique was used to constitute the small groups of mixed academic abilities. Each group consisted of a mixed of low performers, average performers and high performers. The pre-test scores in the mole concept informed the categorization of the students into low performers, average performers and high performers which aided the mixed academic abilities of small groups' formation. By stratified sampling the research participants in the experimental group were put into three strata of low performers, average performers and high performers. By random sampling from the three strata, seven groups of mixed academic abilities in the mole concept were formed. Each group consisted of six participants except two groups where they were seven. The groups were heterogeneous in nature and were maintained throughout the intervention.

Due to the poor achievement of the students in the pre-test and for the purpose of grouping the students to form mixed academic abilities, students with scores between the ranges of 0-9 were designated as low performers, those with scores between the ranges of 10-14 as average performers and finally those with scores between the ranges of 15-30 as high performers. This was as a result of the pre-test being scored out of thirty points, meaning the total score was thirty. This categorization was necessary in order to form the three strata (low performers, average performers and high performers) from which the seven groups of mixed academic abilities in the mole concept were formed. Scores of the pre-test in the experimental group revealed that only seven students obtained scores within the range of 15-30, eleven students got scores from 10-14 and twenty-six students had scores from 0-9. These available scores clearly informed the ranges of scores and the designation as low performers, average performers and high performers so as to form the seven small groups for the study. (Refer to Appendix A for sample pre-test questions and Appendix N for sample students' responses to the questions).

3.5 Research Instruments

The quality of the instruments used in research is very important, for the conclusions researchers draw are based on the information they obtain using these instruments. Accordingly, researchers use a number of procedures to ensure that the inferences they draw, based on the data they collect, are valid and reliable (Fraenkel & Wallen, 2003).

Three research instruments were used for the study. The main instrument for the study was the Mole Concept Achievement Test (MCAT) and the other instruments were the Mole Concept Perception and Attitude Scale (MCPAS) questionnaire and interview. Thus the study adopted both quantitative and qualitative approaches in the data collection. The MCAT and the MCPAS were quantitative while the interview was qualitative in nature. Throwing more light on the concept of test and its usage to obtain research data, McMillan and Schumacher (1997) indicate that the term test refers to the use of test scores as data. This technique involves subject response to either written or oral questions to measure performance trait. A numerical value is obtained as a result of each subject's answers to a standard set of questions. The instrument is used as a way to describe or measure a characteristic of the subject.

Regarding interview, according to Robson (2002), interviewing as a research methodology involves the researcher asking questions and hopes to receive answers from the respondents. Interviews can take place in a group context as well as one - to- one. The

MCPAS as one of the research instruments took the form of the Likert Scale. McMillan and Schumacher (1997) once again state that a scale is a series of gradations, levels or values that describes various degrees of something. Scales are used extensively in questionnaires because they allow fairly accurate assessments of beliefs or opinions. This is because many of our beliefs and opinions are thought of in terms of gradations.

3.5.1 Description of the research instruments

3.5.1.1 Test

The MCAT took the form of both pre-test and post-test. The pre-test was aimed at determining the students' achievement of the mole concept before the intervention or treatment. It was also carried out to determine the achievement of the students in the mole concept to form the basis for placing the two groups or the two intact classes into the experimental group and control group for the study. The structure of the pre-test was both essay type and multiple choice questions on the mole concept. The questions were mainly calculations and some few definitions of terms related to the mole concept. The multiple choice questions were ten and the essay type questions were also ten. The post-test aspect of the MCAT also comprised ten short essay type questions and ten multiple choice questions on the mole concept. The questions were equally mainly calculations and some few definitions of terms related to the mole concept. This was administered to both the experimental and control groups (forty-four participants from each group) after the treatment.

All the test items were drawn from the mole concept contained in the first year integrated science syllabus for the Colleges of Education in Ghana. Some of the questions were past questions from the end-of-semester examination set by the University of Cape Coast and administered to the Colleges of Education in Ghana. The rest of the pre-test and post-test items were developed by the researcher and moderated by two experienced integrated science teachers from the Science Department, Tamale College of Education and two Senior Lecturers from the Science Education Department, University of Education, Winneba for quality. The test scores of both the pre-test and post-test formed the basis for data analysis after they were administered.

The total score of the test was thirty for each pre-test and post-test. The organization or the structure of both the pre-test and post-test were the same. The test was structured two sections (section 'A' and section 'B'). The section 'A' comprised ten multiple choice questions and each question was scored 1 making a total of ten marks. The section 'B' constituted ten questions with score(s) per question ranging from 1 mark to 3 marks depending on the strength of the question making a total of twenty marks. The details of the pre-test and the post-test are attached (Appendix A and Appendix B) respectively. Samples of the students responses to the post-test are attached (Appendix O).

3.5.1.2 Interview Schedule

The interview schedule was developed by the researcher. Bell (1993) asserts that a major advantage of interview is its adaptability. A skillful interviewer can follow up ideas, probe responses and investigate motives and feelings, which the questionnaire can never do. The interview can provide information that a written response would conceal. Questionnaire responses have to be taken at face value, but a response in an interview can be developed and clarified.

Semi- structured interview schedules were used to find out the participants (students) perception and attitude toward the mole concept. The interview schedules offered the participants the opportunity to express themselves by indicating their perceptions and attitudes toward the mole concept. The questions were ten in all and mainly centred on how students perceived the mole concept and their attitude toward it. The questions were both closed and open-ended types. A total of ten students were interviewed, five from each group (experimental and control). The sampling procedure was stratified random sampling due to the heterogeneous nature of the sample (three males and two females from each group). The interview was carried out by the researcher and the responses of the interviewees formed the basis of data analysis. The interview session was recorded and later transcribed. The essence of the interview was to find out whether the views or opinions expressed by the interviewees were consistent with the responses from the questionnaires on their perceptions and attitudes toward the mole concept.

The developed interview schedules (Appendix C) were moderated by supervisor of this study. This was to ensure that the questions were appropriate and served the purpose of the research.

3.5.1.3 Questionnaire

The questionnaires were also developed by the researcher. They took the form of Likert scale and were used to collect data on the students' perception and attitude toward the mole concept. They were twenty items on the scale comprising both positive and negative statements. For example, some of the items were stated as "the mole concept is easy; SA = 5, A = 4, U = 3, D = 2, SD = 1" as a positive statement and "the terms used in the mole concept are scaring; SA = 1, A = 2, U = 3, D = 4 and SD = 5" as a negative statement.

Gay (1987, p. 146) state:

> A Likert scale asks an individual to respond to a series of statements by indicating whether she or he strongly agrees (SA), agrees (A), is undecided (U), disagrees (D), or strongly disagrees (SD) with each statement. Each response is associated with a point value, and an individual's score is determined by summing the point values for each statement. For example, the following point values might be assigned to responses to positive statements: SA = 5, A = 4, U = 3, D = 2, SD = 1. For negative statements, the point values would be reversed, that is SA = 1, A = 2, U = 3, D = 4 and SD = 5.

In Likert scale, respondents are directed to indicate the extent to which they agree or disagree with each statement, and the overall score then suggests whether the individual's attitude is favourable or unfavourable. The Likert scale was chosen due to the advantage that it provides the researcher with the opportunity to carry out statistical analysis. The Likert scale items can be analysed both quantitatively and qualitatively.

The questionnaire was termed as the Mole Concept Perception and Attitude Scale (MCPAS). It comprised two sections; section 'A' and section 'B'. The section 'A' mainly addressed the respondent's biodata while the section 'B' consisted of twenty statements both positive and negative on students' perception and attitude toward the mole concept (Appendix D). The participants were asked to respond to a series of the statements by indicating Strongly Agrees (SA), Agrees (A), Undecided (U), Disagrees (D), or Strongly Disagrees (SD) to each statement. For positive statements, the scoring was as follow: SA = 5, A = 4, U = 3, D = 2, SD = 1. For negative statements, the point values were reversed, that is SA = 1, A = 2, U = 3, D = 4 and SD = 5. Each response indicated the extent of the participant's perception and attitude toward the mole concept. Both the experimental group (N = 44) and the control group (N = 44) responded to the questionnaire.

3.5.2 Reliability of the instruments

Reliability is the degree of consistency that the instrument or procedure demonstrates, whatever it is measuring, it does so consistently (Best & Kahn, 1995). According to Mohsen and Dennick (2011), internal consistency describes the extent to which all the items in a test measure the same concept or construct and hence it is connected to the inter-relatedness of the items within the test. It is therefore necessary that internal consistency should be determined before a test can be employed for research or examination purposes to ensure validity. The instruments (test and questionnaire) were pilot-tested and the reliability coefficients determined to ensure that they were reliable for the study. The instruments were pilot-tested by the researcher himself in Bagabaga College of Education in the Northern Region using twenty first year students. This college was chosen because of its proximity to the researcher and the fact that it has similar characteristics with the study area (Tamale College of Education). Both colleges are in the Tamale Metropolis within the Northern Region. The pilot-testing was necessary because it improved the content validity and reliability of the instruments.

The reliability coefficients of the pilot- tested instruments (pre-test and post-test) were determined using the Kuder-Richardson 20 (KR20) formula. The procedure for determining the reliability coefficient using the Kuder-Richardson 20 (KR20) formula was applied (Appendix E). On the other hand, the reliability of the Likert items was determined using the Cronbach's Alpha reliability coefficient value. This was computed using the Statistical Package for Social Science (SPSS) version 20.0 (Appendix F). The reliability coefficients for the test and the questionnaire as instruments used to collect the data for the study are summarized below (Table 3.1).

Table 3.1: Reliability Coefficients for the Research Instruments

Instrument	Reliability Coefficient
Test	
▪ Pre-test	0.736
▪ Post-test	0.751
Questionnaire	0.851

In determining the appropriateness of the reliability coefficient and its usage in research, George and Mallery (2003) provide the following rules of thumb: "greater than 0.9 is excellent, greater than 0.8 is good, greater than 0.7 is acceptable, greater than 0.6 is questionable, greater than 0.5 is Poor and less than 0.5 is unacceptable" (p. 231).

3.5.3 Validity of the instruments

Validity is that quality of a data-gathering instrument or procedure that enables it to measure what it is supposed to measure (Best & Kahn, 1995). The test items, the questionnaire and the interview schedules were submitted to two experienced integrated science teachers from the Science Department, Tamale College of Education and two Senior Lecturers for moderation.

The test items covered the aspect of the mole concept that are contained in the first year integrated science syllabus for Colleges of Education in Ghana. Some of the test items were past questions from the end-of-semester examination set by the University of Cape Coast and administered to the Colleges of Education in Ghana. This was done to ensure content validity of the test items. The instruments were reviewed by experts to ensure that the items were valid before administering them on the research participants.

3.6 Treatment of the Groups

3.6.1 The experimental group

The experimental group was the group that received the problem-based learning (PBL) approach to teaching. According to Newman (2005), the key features of problem-based learning include learning in small groups, teacher as facilitator, appropriate assessment, tutorial process to stimulate reflection, active participation and application as well as use of 'problems' to stimulate or motivate, contextualize and integrate learning. First year general programme 1 K class (N = 44) was selected as the experimental group for the study after the pre-test scores using the t-test analysis indicated that there was no significant difference between the achievement of the experimental group and the control group in the mole concept.

Taking the features of PBL into consideration, the researcher became a facilitator throughout the period of the treatment. The treatment lasted for four weeks including the conduction of post-test and the administration of Mole Concept Perception and Attitude Scale (MCPAS) to end the treatment process. The research participants in both groups responded to the MCPAS after the treatment. The purpose was to determine the perception and attitude of the students toward the mole concept. The interview schedules were also administered. The experimental group was then put into small groups of seven as already explained under sample and sampling procedure for the treatment using the PBL approach.

Worksheets were prepared by the researcher and supplied to each small group for discussion. The researcher played the key role as a facilitator during the discussion. The discussion on the mole concept lasted for three weeks. Each week, the students met once for a period of two hours. At each meeting, students were provided with worksheets on the mole concept to guide the small groups' discussion. The last week being the fourth week was used for the MCAT (post-test) and the MCPAS after the treatment process. The worksheets were provided on the key areas of the mole concept (Figure 3.2). The key concepts centred on how the mole relates to the mass and molar mass, the number of particles and the Avogadro's constant, the volume and the molar volume. The amount of substance, which is measured in mole, is equal to the mass over the molar mass, it is equal to the number of particles over the Avogadro's constant and it is also equal to the volume per the molar volume. Each worksheet therefore focused on these interrelated concepts to drive home the understanding of the mole concept by the students. Worksheet one centred on the concept of mass and molar mass, worksheet two centred on the concept of the number of particles and the Avogadro's constant and finally worksheet three centred on the concept of volume, molar volume and concentration. The worksheets were used to guide the participants (students) understand the key terms in the mole concept and how they are applied in solving problems relating to the mole concept. Steps (problem-solving guide) to solving problems on the mole concept were provided to the participants.

The concepts of mass and molar mass discussed under worksheet one (WS 1) included definition of mass of a substance, the units for measuring mass, definition of molar mass and its unit of measurement. The relative atomic masses of given elements were also obtained from the periodic table and the students were guided to deduce the molar mass of given compounds. Regarding the concepts of the Avogadro's constant, the number of particles (atoms, molecules, ions) and the mole conversion under worksheet two (WS 2), the students in groups were guided to understand the concepts and apply them in the mole conversion. Worksheet three (WS 3) contained the application of the concepts of volume, molar volume and molar concentration in solving problems relating to the mole concept.

Samples of the worksheets are illustrated as shown below.

Mole Concept Worksheets – Worksheet One (WS1): Mass and Molar Mass.

1. Define mass of a substance.
2. State any two units that can be used to measure mass.
3. Use the periodic table to write out the relative atomic masses of the following elements:
   Na, Ca, Mg, O, Cl, N, S, Fe, Cu, Zn and H
4. What is molar mass of a substance?
5. State the unit of molar mass
6. Use the periodic table to find the molar mass of the following.

i. HCl ii. Ca $(OH)_2$

iii. Na_2CO_3 iv. NaCl

v. CO_2 vi. $NaNO_3$

Worksheet Two (WS2): Avogadro's Constant, Number of Particles and Mole Conversion

Work each of the following problems using the problem solving guide. SHOW ALL WORK.

1. A sample of nitrogen gas consists of 4.22 x 10^{23} molecules of nitrogen. How many moles of nitrogen gas are there? (L= 6.02 x 10^{23}).
2. Calculate the amount of substance (in moles) of 2.5 g of carbon (IV) oxide. (C =12.0, O=16.0).
3. There are 3.010 x 10^{23} particles per mole of CO_2 gas. What amount of CO_2 gas is present? (L = 6.02 x 10^{23}, C =12.0, O =16.0).
4. How many atoms are in 6.2 moles of aluminum? (L = 6.02 X 10^{23}).
5. Calculate the molar mass of 0.05 moles of Sulphur (IV) oxide gas which has a mass of 2.5g.

Worksheet Three (WS3): Mole Conversion (Volume, Molar Volume and Concentration)

Work each of the following problems using the problem solving guide. SHOW ALL WORK.

1. Calculate the amount of substance (mole) in 2.8 dm^3 of CO_2 at s.t.p. ($Vm = 22.4\ dm^3/mol$).
2. What mass of Na_2CO_3 is needed to prepare $0.3dm^3$of 2 $moldm^{-3}$ solution of Na_2CO_3? (Na= 23, C= 12, O=16).
3. 3 mol of hydrogen molecule (H_2) react with 1 mol of nitrogen molecule (N_2) to yield 2 mol of ammonia (NH_3). If the ammonia contains 2.5 mol, how many moles of the nitrogen molecule (N_2) reacted?
4. Determine the number of moles in 0.25M solution of HCl in 250 cm^3.
5. Calculate the concentration in 2.0 g of NaOH dissolved in 1000 cm^3 volumetric flask. (Na =23, O =16, H =1).

The framework of PBL on the mole concept is presented below (Figure 3.2). According to Furio, Azcona, Guisasola and Ratcliffe (2000), the operative definitions of the variables expressed in the mole concept are related through the mass to molar mass, the volume to the molar volume and the number of elementary entities to the Avogadro's constant: $n = m/M$; $n = V/V_m$; $n = N/N_A$ where the connections of 'n' with 'm', 'V' or 'N_A' are established (where M is the molar mass, Vm the molar volume, NA the Avogadro constant, *'n'* is the amount of substance, *'m'* is the mass, *'V'* is the volume and *'N'* is the elementary entities).

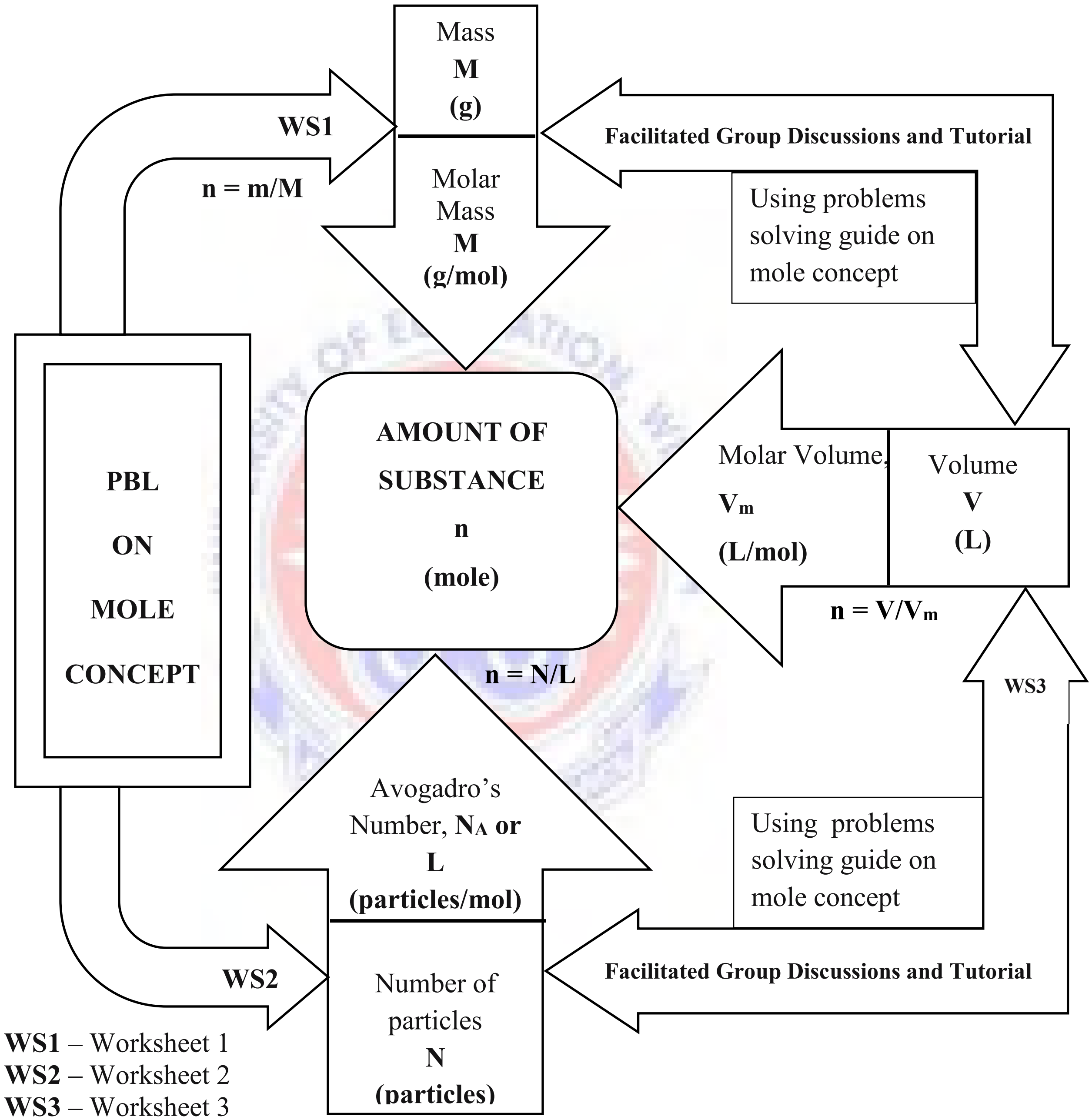

Fig. 3.2: Framework of PBL on the Mole Concept

The steps that guided the students in their small groups' discussions to solve problems on the mole concept were in line with studies that provided the blueprint for practicing to solve problems. Brown, LeMay, Bursten and Murphy (2009, p.89) outlined the following practical steps in problem solving.

> **Step 1: Analyse the problem.** Read the problem carefully to understand. What does it say? Draw any picture or diagram that will help you to visualize the problem. Write down both the data you are given and the quantity that you need to obtain (the unknown).
>
> **Step 2: Develop a plan for solving the problem**. Consider the possible paths between the given information and the unknown. What principles or equations relate the known data to the unknown? Recognize that some data may not be given explicitly in the problem; you may be expected to know certain quantities (such as Avogadro's number) or look them up in tables (such as atomic weights). Recognise also that your plan may involve either a single step or a series of steps with intermediate answers.
>
> **Step 3: Solve the problem.** Use the known information and suitable equations or relationships to solve for the unknown. Dimensional analysis is a very useful tool for solving a great number of problems. Be careful with significant figures, signs, and units.
>
> **Step 4: Check the solution**. Read the problem again to make sure you have found all the solutions asked for in the problem. Does your answer make sense? That is, is it in the ballpark? Finally, are the units and significant figures correct?

Each group therefore was provided with the steps outlined above to guide their discussions as they solve given problems on the mole concept using worksheets. The facilitator and for that matter the researcher first and foremost demonstrated how the given steps are applied by solving a given problem on the mole concept. Per the worksheets provided; groups were made to solve the questions on the worksheets at their individual groups' level. Groups' presentations were carried out and supervised by the facilitator.

3.6.2 The control group

The control group received the traditional lecture-based (TLB) instruction. This group was also selected after the pre-test scores were collated and analysed. Even though there was no significant difference between the achievement of the control group and the experimental group considering the pre-test scores, the mean score of the control group was slightly higher than the experimental group. First year general programme 1 A class was selected as the control group (N = 44). The control group also responded to the MCPAS and the interview schedules before treatment with the traditional lecture-based method.

The teaching method was mainly teacher-centred with little involvement of the students. The students in this group were not put into small groups for discussions of problems related to the mole concept. They were not provided with any problem solving guide. The teacher who was also the researcher assumed the position of a lecturer, but not a facilitator in the teaching and learning process. The participants were not provided with worksheets on the mole concept to try their hands on and to make presentations for the teacher and their peers to comment on. There was no tutorial session for the students in this group. The teaching was textbook based and mainly marker board illustrations. The participants were allowed to ask questions and answers were provided without so much attention to individual students. The control and the experimental groups were within the same institution suggesting that there was a high possibility of both groups sharing information on the interventions. This was controlled by implementing the interventions at separate times. The TLB approach also lasted for four weeks including the conduction of the post-test and administration of MCPAS after the treatment. The last week of the four weeks was used for the post-test and the administration of the MCPAS. The summary of the treatment processes of the experimental and control groups is presented below (Figure 3.3).

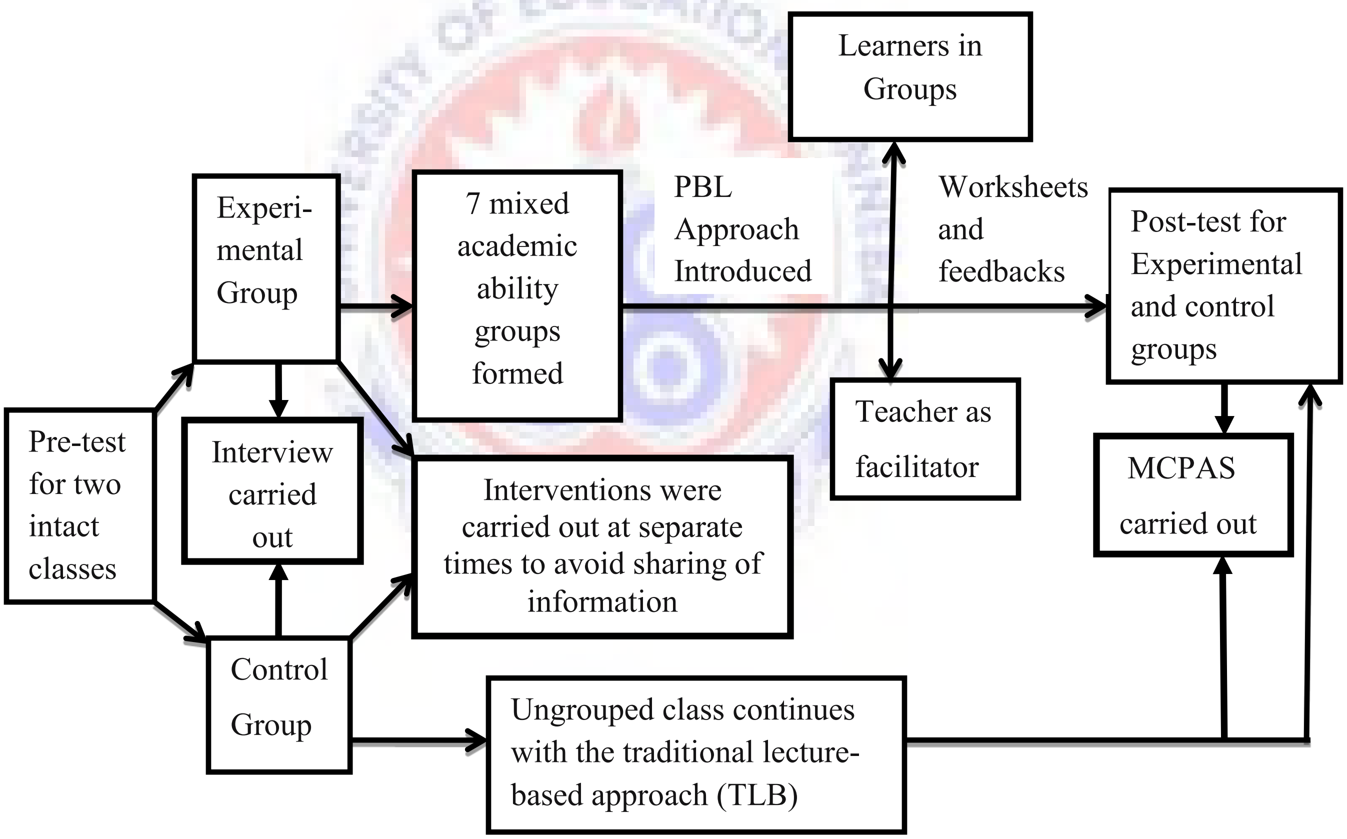

Fig. 3.3: Treatment Process for the Experimental and Control Groups on the Mole Concept

3.7 Methods of Data Collection

The Mole Concept Achievement Test (MCAT) in the form of pre-test and post-test formed the basis of the data. The researcher scored the pre-test and the post-test and generated quantitative data for analysis. The Mole Concept Perception and Attitude Scale (MCPAS) questionnaire also formed the basis for quantitative data for analysis. The interview schedules generated qualitative data for analysis.

Data were collected from the pre-test scores after the researcher together with one of the teachers in the Science Department of Tamale College of Education conducted the pre-test. The researcher could not have conducted the pre-test in the two intact classes all by himself. He therefore engaged one of his colleague trained teachers to assist in carrying out the pre-test. The pre-test was written at the same time lasting for one hour in the two intact classes. The scripts were marked by the researcher and vetted by experts to ensure the scores were in accordance with the marking scheme. The researcher administered the interview in the two intact classes selected for the study after the pre-test. This was done to find out the students' perceptions and attitudes toward the mole concept before the treatment processes.

The post-test and the MCPAS questionnaire were administered to both the experimental and control groups after the treatment period which lasted for four weeks. The post-test was also marked by the researcher and vetted by experts to ensure the conformity of the scores with the marking scheme. The MCPAS questionnaires were administered after the treatment process using the PBL and the TLB approaches on the experimental and the control groups respectively. The idea was to find out the students' perception and attitude toward the mole concept using the PBL and the TLB.

3.8 Data Analysis

The data collected were analysed quantitatively and qualitatively. The data generated from the pre-test, the post-test and the questionnaire were analysed quantitatively while the data generated from the interview schedules were analysed qualitatively. The MCAT in the form of pre-test and post-test, and the Likert scale-based questionnaires that is the MCPAS were subjected to statistical analysis using the t-test. According to McMillan and Schumacher (1997), a t-test is used to determine whether two means are significantly different at selected probability level. Kibos, Wachanga and Changeiywo (2015) also indicated that a t-test is used when dealing with two means because of its superior power to detect differences between two means. The data were analysed with the help of SPSS version 20.0 and Microsoft Excel.

The t-test was used to determine whether there was any significant statistical difference between the mean scores of the students' achievement in the mole concept using the pre-test scores and the post-test scores. It was also used to determine if there was significant statistical difference between the achievement of the students using the PBL and the TLB approaches. Comparison was also made using the t-test to find out if there was significant difference between the perception and attitude of the students toward the mole concept after exposure to the PBL and TLB approaches. Descriptive statistics such as bar charts were also used to present the results.

CHAPTER FOUR

RESULTS AND DISCUSSION

4. 1 Overview

This chapter presents the results and discussion of the study. The pre-test and post-test results were analysed using both unpaired and paired t-test. The results were presented using tables and bar charts according to the research questions. The null hypotheses were statistically tested at the significant level 0.05. The results were discussed based on the research questions.

4.2 Biodata of the Research Participants

The biodata of the research participants, who were entirely students covered their gender (male and female), age ranges, programme of study and level. All the students (participants) selected for the study were level hundred offering general programme. The number of participants in the experimental group (N = 44) was the same as those in the control group (N = 44). Per the organisation of the intact classes at the time of the study, the number of males (N = 22) and females (N = 22) in both the experimental and the control groups was the same. The selection of the research participants in terms of gender disaggregation was evenly distributed (Figure 4.1).

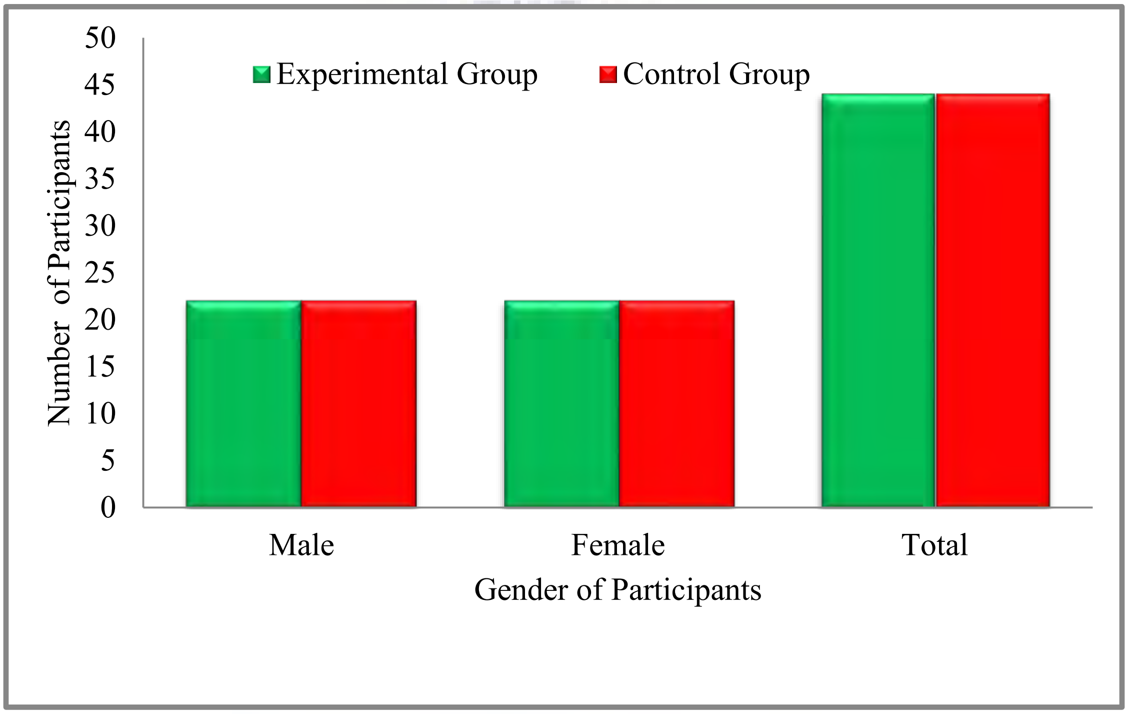

Fig. 4.1: Biodata of Research Participants in terms of Gender

Regarding the ages of the participants, their age ranges were considered instead of individual ages. The participants were within the age ranges of 15 – 20 years and 21- 26 years. The majority of the participants, as many as seventy out of eighty-eight participants selected for the study were within the age range of 21-26 years, while eighteen were in the category of 15 – 20 years. No participant (student) was below fifteen years or above twenty-six years (Figure 4.2).

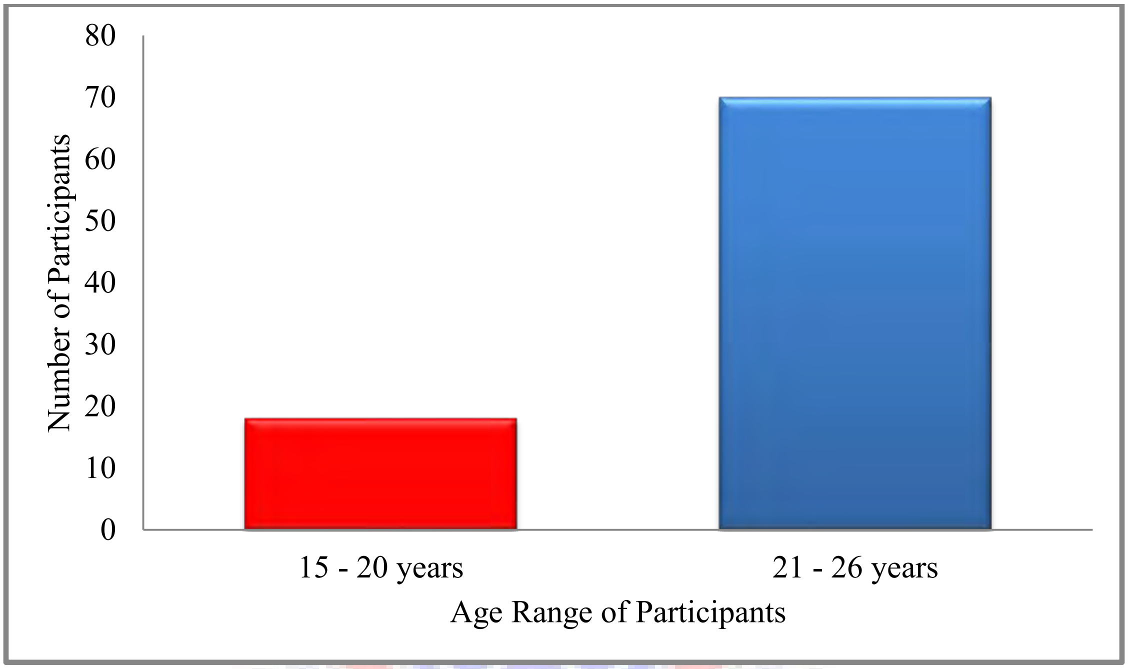

Fig. 4.2: Biodata of Participants in terms of Age

4.3 Research Question One

What is the achievement of the students in the mole concept in the experimental and control groups before the treatment?

H_{01}: There is no significant difference between the achievement of the students in the mole concept in the experimental and control groups before the treatment.

This research question sought to find out the achievement of the students in the mole concept in both the experimental and control groups before the treatment. The achievement of the students in the mole concept before the treatment using the Mole Concept Achievement Test (MCAT) (pre-test) was meant to establish a baseline that ensures parity in terms of achievement between the two groups. It was also to determine the previous knowledge or the entry knowledge of the students in the mole concept before the treatments.

The pre-test scores of the students which were scored out of a total of thirty points in both the experimental and control groups were compared (Figure 4.3). The pass mark or score (baseline) that determined whether a student failed or passed the test was fifteen. Students who scored below fifteen failed the test and those who scored exactly fifteen or above passed the test. The results (Figure 4.3) reveal that ten and eleven students in the control and experimental groups respectively obtained scores within the range of 1-5. Seventeen students per group in both the control and experimental groups had their scores within the range of 6-10. Also nine students in the control group and ten students in the experimental group obtained scores within the range of 11-15. Within the range of 16-20 scores, seven and five students in the control and experimental groups respectively got their scores in that range. Only one student per group in both the control and experimental groups obtained a score within a range of 21-30. The results show that the majority of the students, seventy-four, that is thirty-six in the control group and thirty-eight in the experimental group, out of a total of eighty-eight students obtained scores starting from one to fifteen. As few as fourteen students (eight in the control group and six in the experimental group) out of a total of eighty-eight had scores above fifteen (Figure 4.3).

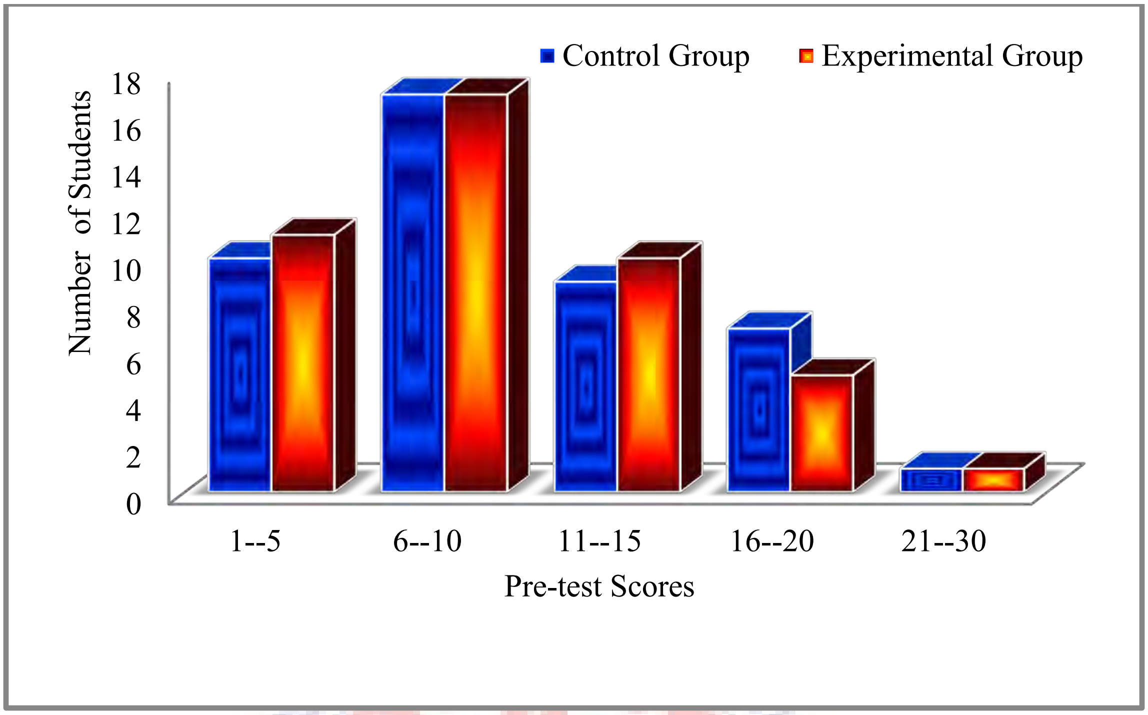

Fig. 4.3: Pre-test Scores between the Experimental and the Control Groups

The pre-test scores of both the experimental and control groups were also subjected to unpaired t-test analysis to find out if there was any significant difference between the achievements of the two groups in the mole concept. The results (Table 4.1) reveal that there is no significant difference between the mean scores of the two groups and therefore their previous knowledge in the mole concept is the same (p = 0. 877). Therefore we fail to reject the null hypothesis. The detailed analysis is attached (Appendix H).

Table 4.1: Unpaired Samples t-test of Pre-test Scores of Experimental and Control Groups

Group	N	M	SD	df	*t-value*	*p-value*
Experimental	44	9.3	5.04	86	0.156	0.877
Control	44	9.5	5.22			

N (sample size), M (Mean), SD (standard deviation) and df (degree of freedom)

The same level of the students' achievement in the pre-test prior to the treatments for the experimental and the control groups meant that no group was above the other in terms of their achievement in the mole concept. The results also reveal that even though the students came from different Senior High Schools in the country to Tamale College of Education, their level of achievement in the mole concept in the pre-test was equivalent. This indicates that among the students who took the test in the mole concept, the difficulties they encountered in responding to the pre-test questions were similar. The rather abysmal achievement of the students in the pre-test was in line with a study by Case and Fraser (1999), which contends that students have acute difficulties in dealing with the abstract concepts required of them to perform stoichiometric calculations using the mole concept. The baseline in terms of achievement in the mole concept between the two groups was statistically the same. This therefore formed the basis for determining the effect of the PBL on the students' achievement in the mole concept.

The pre-test questions on the mole concept were basic questions derived from both the integrated science syllabi at the Senior High School and the Colleges of Education levels in Ghana. The questions basically centred on the definition of mole of a substance, its unit of measurement, definitions of molar mass and molar volume and their units of measurement. The rest of the questions were calculations on mole conversion that involves mass of a substance, molar mass, number of particles (atoms, molecules), the Avogadro's number, molar concentration and molar volume. Although the questions were basic which the students were supposed to have learnt at the Senior High School level, their achievement was below expectation and that clearly indicates that they really have problems learning the mole concept. No wonder their achievement in the pre-test was the same before the treatments.

4.4 Research Question Two

What is the difference in achievement of the students in the mole concept using the PBL approach and the TLB method?

H_{02}: There is no significant difference between the students' achievement in the mole concept using the PBL approach and the TLB method.

This question aimed at comparing the achievement of the students in the mole concept using two pedagogical approaches (PBL and TLB). The main aim is to determine the effect of PBL on the students' achievement in the mole concept. The two treatments PBL and TLB were carried out in the experimental and control groups respectively. Considering the results of the study (Figure 4.4), whereas in the control group seven, eleven and ten students obtained test scores within the ranges of 1-5, 6-10 and 11-15 respectively, no student had a score within the ranges of 1-5 and 6-10 in the experimental group. Only two students got scores within the range of 11-15. Eleven and seven students got scores within the range of 16-20 in the control and experimental groups respectively. On the other hand, as many as thirty-five students obtained scores within the range of 21-30 in the experimental group while in the control group only five students had scores within that same range. Comparatively, sixteen students obtained scores above fifteen (the pass mark) in the control group, whilst as many as forty-two students got scores above fifteen in the experimental group (Figure 4.4).

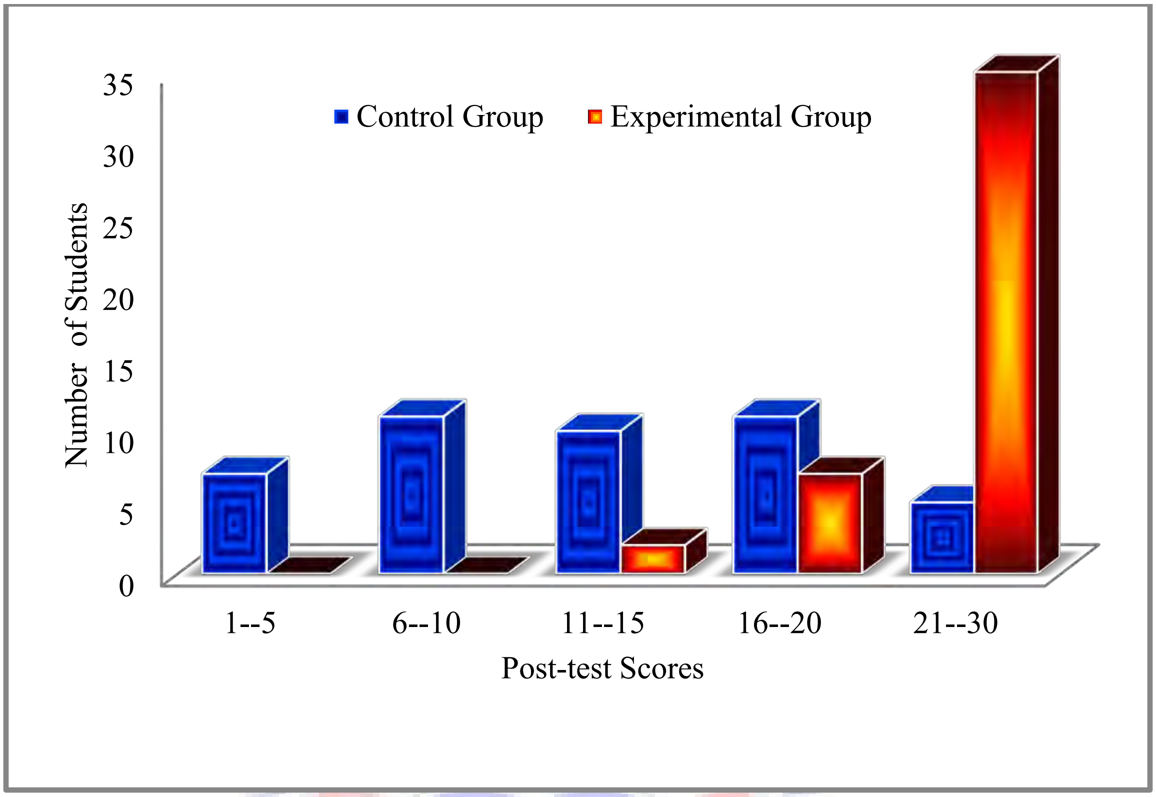

Fig. 4.4: Post-test Scores between the Experimental and the Control Groups.

The unpaired samples t-test was used to determine the difference in achievement in the mole concept between the students in the experimental and control groups using the PBL approach and the TLB method respectively. The results indicate that the students in the experimental group had higher achievement in the mole concept than their control group counterparts since the mean score of the experimental group was significantly different from the mean score of the control group (p = 0.000) (Table 4.2). Therefore the null hypothesis was rejected. The detailed analysis is attached (Appendix I). The significant difference in the mean scores giving a higher mean score in the experimental group over the control group (Table 4.2) is attributable to the treatment, thus the PBL is more effective than the TLB.

Table 4.2: Unpaired Samples t-test of post-test Scores of Experimental and Control Groups

Group	N	M	SD	df	*t-value*	*p-value*
Experimental	44	23.7	3.74	86	9.923	0.000
Control	44	12.7	6.34			

N (sample size), M (Mean), SD (standard deviation) and df (degree of freedom)

Comparing the achievement of the students in the pre-test and post-test within the experimental group, the results (Figure 4.5) reveal that eleven students got scores within the range of 1-5 in the pre-test while no student had a score in that same range in the post-test. As many as seventeen students obtained scores within the range of 6-10 in the pre-test; however, no student had a score within that same range in the post-test. Ten and two students had scores within the range of 11-15 in the pre-test and post-test respectively. In the range of 16-20 scores, five and seven students obtained scores in the pre-test and post-test respectively. Only one student had a score within the range of 21-30 scores in the pre-test while as many as thirty-five students obtained scores within that same range.

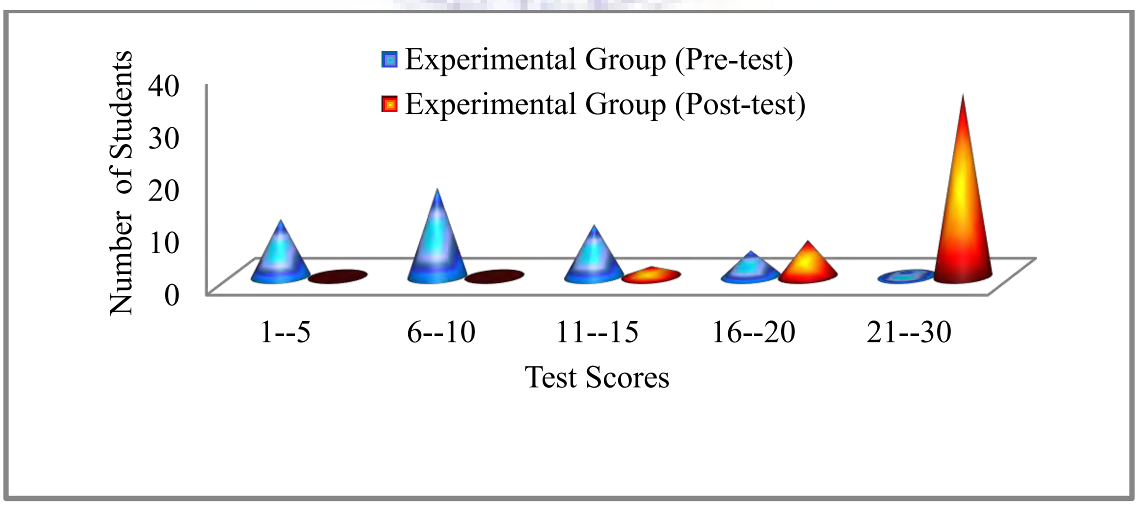

Fig. 4.5: Pre-test and Post-test Scores in the Experimental Group

The paired samples t-test was used to determine the effect of the PBL on the students' achievement in the mole concept in the experimental group using the pre-test and the post-test scores within that same group. The results (Table 4.3) reveal that the students' achievement in the post-test was better than their achievement in the pre-test since the mean score of the post-test was significantly different from the mean score of the pre-test (p = 0.000). The detailed analysis is attached (Appendix J). The higher students' achievement in the post-test over the pre-test due to the mean gain in the post test over the pre-test (Table 4.3) was influenced by the treatment (PBL) rather than just the group. The mean score of the post-test was above the pass mark (fifteen).

Table 4.3: Paired Samples t-test of Pre-test and Post-test Scores of the Experimental Group

Group	N	M	SD	df	*t-value*	*p-value*
Experimental (Post-test)	44	23.7	3.74	43	17.078	0.000
Experimental (Pre-test)	44	9.3	5.04			

N (sample size), M (Mean), SD (standard deviation) and df (degree of freedom)

Comparing the achievement of the students in the pre-test and post-test within the control group, the results (Figure 4.6) reveal that, ten and seven students obtained scores within the range of 1-5 in the pre-test and post-test respectively. In the range of 6-10, seventeen students had scores in the pre-test and eleven students had scores within that same range in the post-test. Nine and ten students also obtained scores within the range of 11-15 in the pre-test and post-test respectively. Seven students had scores within the range of 16-20 in the pre-test while eleven students got scores within that same range in the post-test.

In the range of 21-30 scores, only one and five students obtained scores in the pre-test and post-test respectively.

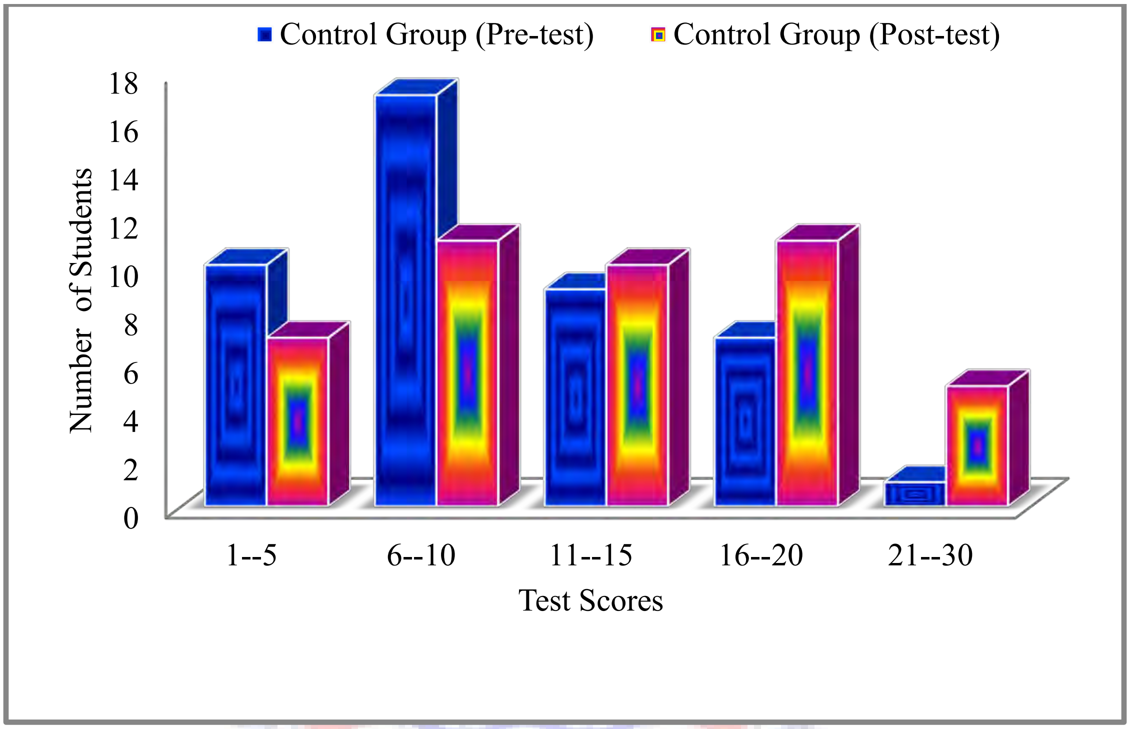

Fig. 4.6: Pre-test and Post-test Scores in the Control Group

The paired samples t-test was also used to find out the difference in achievement in the mole concept among the students using the pre-test and the post-test scores within the control group. The results (Table 4.4) show that there was a significant difference between the students' achievement in the post-test and the pre-test. The mean score of the post-test was significantly different from the mean score of the pre-test (p = 0.011). The detailed analysis is attached (Appendix K). Although there was a significant difference in the students' achievement between the pre-test and post-test scores within the control, the mean score of the post-test was below the pass mark (fifteen). Thus the TLB method of teaching was not as effective as the PBL approach.

Table 4.4: Paired Samples t-test of Pre-test and Post-test Scores of the Control Group

Group	N	M	SD	df	*t-value*	*p-value*
Control (Post-test)	44	12.7	6.34	43	2.655	0.011
Control (Pre-test)	44	9.5	5.22			

N (sample size), M (Mean), SD (standard deviation) and df (degree of freedom)

The results of the study in general reveal that the students who were taught with the PBL approach in the mole concept did significantly better than those taught with the TLB method. The PBL has proved more effective in improving the students' achievement in the mole concept than the TLB. The students' achievement in the post-test in the mole concept in the experimental group was significantly higher than those in the control group. The results were in line with a study by Kehinde (2005), which indicated that students taught using the problem-solving approach perform significantly better than those taught using the lecture method approach. The results also confirmed Shehu (2015), a study conducted on the effect of problem-solving instructional strategies on students' learning outcomes in Senior Secondary School chemistry, revealing that students taught using problem-solving perform significantly better than those taught through lecture method in improving students' achievement in the mole concept. Within the same group (experimental group), the post test results were comparatively better than the pre-test results attesting to the effectiveness of the PBL in yielding better achievement among students in the mole concept.

On the contrary, the students taught with the TLB showed lower achievement in the mole concept compared to those taught with PBL. No wonder studies reveal that problem-solving is a prominent feature in the learning of science and its neglect could have negative effect on students' learning outcome in the sciences (West, 1992; Orji, 1998; Adeoye, 2000). According to Fatoke and Olaoluwa (2014), the conventional lecture method of teaching chemistry proved less effective than the problem-solving method. One of the reasons for the better achievement in the mole concept using the PBL over the TLB confirmed a study by Raimi and Adeoye (2004), which contends that the superiority of problem based learning strategy over the conventional method could be attributed to the logical and sequential manner with which instructions are presented in problem based technique and practical skills teaching. The rather low achievement of the students in the mole concept as they were taught using the TLB confirms a study by Hirca (2011), that argues that in traditional science lessons, teachers come to teach and students memorise or mimic their acts without understanding and retaining whatever that is taught and learnt.

The students' application of knowledge, problem-solving skills, higher-order thinking, and self-directed learning skills in the PBL under this study resulted in their higher achievement in the mole concept than those taught with the TLB. This agrees with the study of Hung (2008), which asserts that problem-based learning (PBL) appears to be the most innovative instructional method conceived and implemented in education with the aim of enhancing students' application of knowledge, problem solving skills, higher-order thinking, and self-directed learning skills. In PBL, students work in groups, have the opportunity to solve several questions and direct their own learning as opposed to TLB where students are simply given lectures with no room for working in groups as well as direct their own learning. The achievement of the students in the mole concept in the experimental group using the PBL approach confirmed the study of Savery (2006), which observed that PBL is an instructional approach that has been used successfully for over 30 years and continues to gain acceptance in multiple disciplines.

In the PBL, the learners were placed in the centre of the learning process with the teacher's role being a facilitator. With worksheets on various aspects of the mole concept, the students in groups solved several questions that yielded a better post-test achievement in the mole concept than those treated with TLB. The advantage of working in groups as in the context of PBL aided the students to perform better than their counterparts who were exposed to the TLB where working in groups was less emphasized. There was similarity between the better achievement of the students in the mole concept as a result of PBL and the study of Burke (2011) on advantages of working in groups, emphasising that groups stimulate creativity, help people remember group discussions better, foster learning and comprehension and decisions that students help make yield greater satisfaction. The results of the study also agree with the study of Akar (2005), which posited that the constructivist approach to teaching enables students to perform better in chemistry achievement test than the traditional lecture method. This is because the students in the constructivist group have the opportunity to benefit from discussion and interaction with peers than the traditional lecture method.

4.5 Research Question Three

What are the students' perceptions and attitudes toward the mole concept using the PBL and the TLB method?

H_{03}: There is no significant difference between the students' perceptions and attitudes toward the mole concept using the PBL and the TLB method.

This research question sought to find out the perceptions and attitudes of the students toward the mole concept after the treatments in both the experimental and control groups. Likert scale-based questionnaires were used comprising twenty statements of which nine were positive statements and eleven were negative statements based on the students' perceptions and attitudes toward the mole concept. The positive statements were scored as SA = 5, A = 4, U = 3, D = 2, SD = 1 and the negative statements were scored as SA = 1, A = 2, U = 3, D = 4 and SD = 5.

Per the students' rating of their perceptions and attitudes toward the mole concept, the 5-point Likert scale was re-organised to 3-point Likert scale during the analysis of the data using percentages. Thus strongly agree (SA) and agree (A) responses were combined as one to indicate agree and the strongly disagree (SD) and disagree were also combined as one to indicate disagree. However, the responses for undecided still remained as they were. The data were analysed using frequency distribution statistics where the percentages for agree, undecided and disagree were presented using tables. The students' perceptions and attitudes toward the mole concept were determined based on the percentage scores.

The students' perception and attitude rating of the mole concept in the experimental group based on positive statements was examined (Table 4.5). The results reveal that 88.7 % of the students agreed that the mole concept is easy, 6.8 % of the students disagreed while 4.5 % of them were undecided. 95.4 % of the students indicated that they were comfortable learning the mole concept while 2.3 % of them disagreed and 2.3 % also undecided. 97.7 % of the students did disagree that the mole concept was well taught at the senior high school level, 2.3 % agree that it was well taught at the senior high school level and no student was undecided about this perception. 95.5 % of the students agreed that they can do well in mole concept exams, 2.3 % of them were undecided while 2.3 % disagreed. 88.6 % of the students also agreed that they enjoy solving problems relating to the mole concept, 6.8 % were undecided, but 4.5 % disagreed that they enjoy solving problems relating to the mole concept. As to whether the mole concept is needed to learn other chemistry topics, 61.4 % agreed, 15.9 % were undecided and 22.7 % disagreed. On the attitude that I easily understand the symbols and units used in the mole concept, 84.1 % of the students agreed, 6.8 % were undecided and 9.1 % disagreed. Last but not least, on the positive statements measuring the perceptions and attitudes of the students toward the mole concept, 27.3 % agreed that they like chemistry of their career, 6.8 % were undecided and 65.9 % disagreed (Table 4.5).

Table 4.5: Students' Perception and Attitude Rating of the Mole Concept in the Experimental Group Based on Positive Statements.

No.	Perception and Attitude Items	Agree (%)	Undecided (%)	Disagree (%)	Total (%)
1.	The mole concept is easy	88.7	4.5	6.8	100
2.	I am comfortable learning the mole concept	95.4	2.3	2.3	100
3.	Chemistry is satisfying	50	15.9	34.1	100
4.	The mole concept is well taught at the senior high school level	2.3	0.0	97.7	100
5.	I can do well in mole concept exams	95.4	2.3	2.3	100
6.	I enjoy solving problems relating to the mole concept	88.6	6.8	4.5	100
7.	The mole concept is needed to learn other chemistry topics	61.4	15.9	22.7	100
8.	I easily understand the symbols and units used in the mole concept	84.1	6.8	9.1	100
9.	I like chemistry because of my career	27.3	6.8	65.9	100

Sample size (N) = 44.

The negative statements relating to the students' perceptions and attitudes toward the mole concept in the experimental group were examined (Table 4.6). The results show that 79.5 % of the students disagreed that chemistry is a difficult subject probably due to how they understood the mole concept when taught using the PBL approach. 18.2 % agreed while 2.3 % were undecided. Responding to whether there are too many calculations in the mole concept, 79.5 % of the students agreed, 20.5 % disagreed and no student was undecided. 54.5 % disagreed that they wish they did not have to take chemistry as a course, 27.3 % agreed and 18.2 % were undecided. The statement that the mole concept is for pure science students, 84.1 % disagreed, 11.4 agreed and 4.5 % were undecided.

However, 61.4 % of the students agreed that understanding the mole concept needs chemistry background, 38.6 % disagreed and no student was undecided.

As many as 90.9 % of the students disagreed that the terms used in the mole concept are scaring, 6.8 % agreed while 2.3 % were undecided. The perception that mole concept lessons are boring, 95.5 % of the students disagreed to that, 4.5 % were undecided and no student agreed. 68.2 % of the students disagreed that the mole concept is confusing, 27.3 % agreed while 4.5 % were undecided. On the other hand, the statement that I do well in other subjects than chemistry, 65.9 % of the students agreed, 11.4 % were undecided and 22.7 % disagreed. The perception that the mole concept is not practical, 59.1 % of the students disagreed, 6.8 % were undecided while 34.1 % agreed. Also, the statement that I do not understand what the mole concept is all about, as many as 90.9 % of the students disagreed with the statement, 9.1 % agreed and no student was undecided (Table 4.6).

Although the statements were negative, one would have expected the students (respondents) to agree with most statements, rather they disagreed. For example statements such as; chemistry is a difficult subject, the mole concept is for pure science students, the terms used in the mole concept are scaring, mole concept lessons are boring, the mole concept is confusing, the mole concept is not practical and I do not understand what the mole concept is all about. The stance of the students was influence by the constructivist approach to teaching thus their exposure to PBL. Very few students (below 20 %) agreed with each of the aforementioned negative statements about the mole concept.

Table 4.6: Students' Perception and Attitude Rating of the Mole Concept in the Experimental Group Based on Negative Statements.

No.	Perception and Attitude Items	Agree (%)	Undecided (%)	Disagree (%)	Total (%)
1.	Chemistry is a difficult subject	18.2	2.3	79.5	100
2.	There are too many calculations in the mole concept	79.5	0.0	20.5	100
3.	I wish I did not have to take chemistry as a course	27.3	18.2	54.5	100
4.	The mole concept is for pure science students	11.4	4.5	84.1	100
5.	Understanding the mole concept needs chemistry background	61.4	0.0	38.6	100
6.	The terms used in the mole concept are scaring	6.8	2.3	90.9	100
7.	Mole concept lessons are boring	0.0	4.5	95.5	100
8.	The mole concept is confusing	27.3	4.5	68.2	100
9.	I do well in other subjects than chemistry	65.9	11.4	22.7	100
10.	The mole concept is not practical	34.1	6.8	59.1	100
11.	I do not understand what the mole concept is all about	9.1	0.0	90.9	100

Sample size (N) = 44.

In the control group where the TLB approach was the intervention, the students' perceptions and attitudes toward the mole concept were rated based on positive statements (Table 4.7). The statement that the mole concept is easy, 47.7 % of the students disagreed, 40.9 % agreed while 11.4 % were undecided. The attitude that I am comfortable learning the mole concept, 52.3 % of the students agreed, while 13.6 % were undecided, 34.1 % disagreed. Since the mole concept is a component of chemistry, regarding the students' attitude that chemistry is satisfying, 50.0 % of the students disagreed, 22.7 % were undecided whereas 27.3 % agreed. The statement that the mole concept is well taught at the senior high school level, 65.9 % of the students disagreed, 25.0 % agreed while 9.1 % were undecided. 59.1 % of the students also agreed that they can do well in mole concept exams, 11.4 % were undecided and 29.5 % disagreed. Again, 52.3 % of the students disagreed that they enjoy solving problems relating to the mole concept, 29.5 % agreed while 18.2 % were undecided. 65.9 % agreed that the mole concept is needed to learn other chemistry topics, 18.2 % were undecided and 15.9 % agreed. I easily understand the symbols and units used in the mole concept, 59.1 % agreed to the statement, 6.8 % were undecided and 34.1 % agreed. Also the statement that I like chemistry because of my career, 47.7 % disagreed, 40.9 agreed and 11.4 % undecided (Table 4.7).

Table 4.7: Students' Perception and Attitude Rating of the Mole Concept in the Control Group Based on Positive Statements.

No.	Perception and Attitude Items	Agree (%)	Undecided (%)	Disagree (%)	Total (%)
1.	The mole concept is easy	40.9	11.4	47.7	100
2.	I am comfortable learning the mole concept	52.3	13.6	34.1	100
3.	Chemistry is satisfying	27.3	22.7	50.0	100
4.	The mole concept is well taught at the senior high school level	25.0	9.1	65.9	100
5.	I can do well in mole concept exams	59.1	11.4	29.5	100
6.	I enjoy solving problems relating to the mole concept	29.5	18.2	52.3	100
7.	The mole concept is needed to learn other chemistry topics	65.9	18.2	15.9	100
8.	I easily understand the symbols and units used in the mole concept	59.1	6.8	34.1	100
9.	I like chemistry because of my career	40.9	11.4	47.7	100

Sample size (N) = 44.

Last but not least, the students' perception and attitude rating of the mole concept in the control group based on negative statements was presented (Table 4.8). Regarding the perception that chemistry is a difficult subject, 70.5 % of the students agreed, 6.8 % were undecided and 22.7 % disagreed. 88.6 % of the students agreed that there are too many calculations in the mole concept, 2.3 % were undecided while 9.1 % disagreed. 50.0 % of the students agreed that they wish they did not have to take chemistry as a course, 11.4 % were undecided and 38.6 % agreed. Responding to the statement that the mole concept is for pure science, 63.6 % of the students agreed, 4.5 % of them were undecided and 31.9 % disagreed. Similarly, 77.3 % of the students agreed that understanding the mole concept needs chemistry background, 11.4 % were undecided while 11.3 % disagreed. 52.3 % of the students held the perception that the terms used in the mole concept are scaring, 43.2 % disagreed and 4.5 % undecided. 52.2 % of the students disagreed that the mole concept lessons are boring, 11.4 % were undecided and 36.4 % agreed. On the other hand, the perception that the mole concept is confusing, 68.2 % of the students agreed, 11.4 were undecided while 20.4 % disagreed. Also, 75.0 % of the students agreed that they do well in other subjects than chemistry, 4.5 % were undecided and 20.5 % agreed. Responding to the statement that the mole concept is not practical, 47.7 % of the students agreed, 47.8 % disagreed while 4.5 % were undecided. Again, 59.1 % of the students agreed that they do not understand what the mole concept is all about, 4.5 % were undecided and 36.4 % disagreed (Table 4.8).

Table 4.7: Students' Perception and Attitude Rating of the Mole Concept in the Control Group Based on Negative Statements.

No.	Perception and Attitude Items	Agree (%)	Undecided (%)	Disagree (%)	Total (%)
1.	Chemistry is a difficult subject	70.5	6.8	22.7	100
2.	There are too many calculations in the mole concept	88.6	2.3	9.1	100
3.	I wish I did not have to take chemistry as a course	50.0	11.4	38.6	100
4.	The mole concept is for pure science students	63.6	4.5	31.9	100
5.	Understanding the mole concept needs chemistry background	77.3	11.4	11.3	100
6.	The terms used in the mole concept are scaring	52.3	4.5	43.2	100
7.	Mole concept lessons are boring	36.4	11.4	52.2	100
8.	The mole concept is confusing	68.2	11.4	20.4	100
9.	I do well in other subjects than chemistry	75.0	4.5	20.5	100
10.	The mole concept is not practical	47.7	4.5	47.8	100
11.	I do not understand what the mole concept is all about	59.1	4.5	36.4	100

Sample size (N) = 44.

In finding out the difference between the students' perceptions and attitudes toward the mole concept using the PBL and the TLB methods, the unpaired samples t-test was used to determine which treatment method yields positive perceptions and attitudes generally. The responses from the Likert scale-based questionnaires by the students in the experimental and control groups were quantified as scores for the t-test analysis between the two groups. The results (Table 4.9) reveal that there was a significant difference between the students' perceptions and attitudes toward the mole concept using the PBL in the experimental group and the TLB in the control group. The mean score of the experimental group was significantly different from the mean score of the control group (p = 0.000). The gain in the mean score of the experimental group over the control group reveals that the students showed positive perceptions and attitudes toward the mole concept when the PBL intervention was used than those in the control group where the method was the TLB. Therefore the null hypothesis was rejected. The detailed analysis is attached (Appendix L).

Table 4.8: Unpaired Samples t-test of the Students' Perception and Attitude Scores in Experimental and Control Groups.

Group	N	M	SD	df	*t-value*	*p-value*
Experimental	44	69.4	9.16	86	6.921	0.000
Control	44	54.7	10.74			

Per the outcome of this study, where the students were exposed to the PBL, the majority of the students (about 88.7 %) believed that the mole concept is easy and comfortable to learn. However, prior to the treatment using the PBL, almost all the students who were interviewed did indicate that the mole concept is difficult. The positive influence of the students' attitude and perception toward the mole concept was as a result of their exposure to the PBL. A good number of the students (about 88.6 %) also did indicate that it is enjoyable solving problems relating to the mole concept and that the symbols and units used in the mole concept are easily understood. The students' positive perception and attitude toward the mole concept particularly in the experimental group was as a result of the constructivist approach to teaching. This study outcome was in line with the study by Uzuntiryaki and Geban (2004), which centred on the effectiveness of instruction based on constructivist approach on students' understanding of chemical bonding and the results of the study indicated that students instructed by the constructivist approach had more positive attitudes toward chemistry as a school subject than students taught by the traditionally designed chemistry instruction. The experimental group and for that matter, the group in the PBL class had better achievement in the mole concept than their control group counterparts due to the positive attitude and perception toward the mole concept.

On the contrary the students exposed to the TLB still portrayed negative perceptions and attitudes toward the mole concept. The achievement of the students in the mole concept in the TLB class was low and this also accounted for their negative attitude and perception toward the mole concept as indicated by their responses in the Likert scale-based questionnaires. In the TLB, the teaching intervention did not influence the perceptions and attitudes of the students in the mole concept positively and this confirmed a study by Chepkorir (2013), which asserts that students themselves contribute to their own failure in Chemistry. Their negative attitudes, lack of interest and lack of confidence are all contributing factors. A good number of the students (70.5 %) taught by the TLB approach still have the perception that chemistry in general is a difficult subject and this agrees with a study by Sirhan (2007), which noted that chemistry is often regarded as a difficult subject, which sometimes repels learners from continuing with its studies. Also, a study by Ayodele (2011) shared similar concerns and revealed that certain concepts such as the mole concept, chemical reactions and others require adequate knowledge of basic mathematical concepts in order to cope with them, the factor which probably makes chemistry one of the most intellectually demanding subjects.

Most of the students (88.6 %) taught with the TLB approach continue to hold the perception that there are too many calculations in the mole concept. The students' responses to the Likert scale-based questionnaires revealed that the mole concept was not properly taught at the Senior High School level. The majority of the students (about 64 %) perceived that the mole concept is for pure science students and that for one to study the mole concept, one needs chemistry background. 68.2 % of the students exposed to the TLB method in their response to the Likert scale-based questionnaires indicated that the mole concept is confusing as this confirmed a study by Larson (1997), which argues that students may fail to construct meaningful understandings of the mole concept for the following reasons: inconsistency between the instructional approaches of the textbook and teacher, confusing mole concept vocabulary, students' mathematical anxiety, learners' cognitive levels, and lack of practice in problem-solving.

On the interview schedules, prior to the treatments in the experimental and control groups, five students (participants) from each group were randomly sampled and interviewed on their perceptions and attitudes toward the mole concept. The participants were designated as 'Participant A_E', 'Participant B_E', 'Participant C_E', and so on from the experimental group. In the control group, they were designated as 'Participant A_C', 'Participant B_C', 'Participant C_C', and so on. The letters A, B, C, and so on were in the order in which the students were interviewed. The subscripts E and C attached to the letters denoted experimental and control respectively. The results based on the interviews which were recorded and transcribed were presented according to the responses of the participants.

Through the interview, the views of the participants were sought on the question "Which of the following topics in the chemistry aspect of integrated science do you find difficult to understand (I) Bonding (II) Mixtures (III) Compounds (IV) Mole Concept (V) Atomic Structure?" The response according to one of the participants in the experimental group stated as:

> "Bonding and mole concept…… mole concept deals with calculations, so before you will be able to understand it better, you have to get the concept then the formula to be able to substitute into whatever question you get so you have to sit down, study, get enough time to study it on your own before you get the whole idea" (Participant B_E).

On the same question, another participant from the experimental group responded to it as:

> "Mole concept …… because for my previous school, I have not been taught well but I know the bonding now it is being taught, the mixture I know, I understand it and the compound too I understand it, for the formulars I understand it but how to use it like when you are being asked the question, you know that this one I know it but sometimes when you see the question you begin to frighten and you will not even think of tackling the question or even reading it even if you know the things because of how it is" (Participant C_E).

Last but not least, the third participant designated as 'Participant D_E' from the experimental group responded to the question as:

> "Mole concept is the most difficult among these …… because of the calculations and also when the question is given out how to deduce the exact formula to solve and get the right answer for that particular question is somehow very difficult if you don't look at it critically".

The responses of the interviewed participants from the control group based on the same question were presented as shown below. One of the participants in the control group out of the five participants in response to the question indicated that:

> "Mole concept is always complicated ….. because of the calculation and the starting point; we didn't have much understanding about the topic because of that when we proceeded here if master is teaching we don't follow up like the other subjects that is the reason why" (Participant A_C).

Another participant in the control group responded to the question by indicating that;

> "Mole concept ….because any time I try to tackle question on it I always easily get confused because the masters when they get there they just brush through it and just jump to the next topic. They don't put much effort to make sure that students understand and the few that know how to understand, immediately they say they understand they just go ahead and say we should contact them to explain it to us" (Participant C_C).

'Participant D_C' in response to the question did indicate that, "mole concept…. it comes with some kind of technical language that need some kind of attention and some level of thinking to be able to understand it".

One of the interview questions also sought to find out the attitude of the students toward the three components (biology, chemistry and physics) of the integrated science studied at the Senior High School level. Thus the question was posed as "Which of these three aspects in the Senior High School integrated science do you like most; chemistry, biology and physics"? The choice of the participants was backed with reasons. These were the responses of the participants to the question from the experimental group. The response from 'Participant A_E' stated: "Biology…. it deals with human relationship such…. reproductive of human making it easy. I don't like chemistry because of compound like chlorine…..the balancing of equations". Also, responses from one of the participants indicated that:

> "Biology…..because at the Senior High School level the teachers had enough time to teach it better and things were around in the Biology office so you could observe it yourself, do the practical by going round to observe it. So it deals with things around, things we saw every day and mostly things that are related to the human" (Participant B_E).

The response of another participant in the experimental group was noted as:

> "Biology ….. even if you are not taught and you read it yourself, it is understandable, but chemistry unless you find someone for the person to teach you well even if you make a slight mistake in chemistry you will deviate in the question, but biology it's understandable" (Participant C_E).

The response of 'Participant D_E' to the question indicated: "Biology…..because is a reading subject and it is easy to understand without being guided". In response to the question "Which of these three aspects in the Senior High School integrated science do you like most; chemistry, biology and physics"?, the following were the responses of the students from the control group. According to one of the participants, he stated that:

> "Biology…..because most chemistry and physics questions involve calculation and at time you have to be conscious of your calculation, little mistake will make that aspect interfere the other step so because of that you can't be pardoned if you make any little mistake and your answer will be wrong….Most at times the teachers in the Senior High School level, they don't take their time to explain things to detail that is why we prefer other subjects to chemistry because they don't explain it to our understanding" (Respondent A_C).

In response to the same question, the participant indicated:

> "Biology…. because it involves a lot of readings and sometimes when you read it you get to understand, but the chemistry aspect too sometimes I do not understand but the way the teachers always start with it they discourage some of us to put on our best especially back at our Senior High School and Junior High School, our science teachers were not just doing well at all concerning the chemistry aspect unlike the biology teachers" (Participant C_C).

Another participant did indicate that; "Biology….because it is quite associated with living things including myself and most of the things explained there are quite understandable. You can easily deduce understanding from it easily. Biology is quite self-explanatory" (Participant D_C).

There was another question that aimed at finding out the attitude of the students toward the mole concept in the area of fear. The question was posed as: "Do you get frightened or scared when you are faced with questions involving the mole concept"? Some of the responses given by the participants from the experimental group were indicated as:

> "Yes…..since I have not been taught well and I have been given the question and you know that if you are not able to answer it you will lose a mark. So even if you know that this one I have to answer, but you don't know how to approach the question, you just do it any how you feel like……" (Participant C_E).

According to one of the participants in answering the question, said: "……in a situation I'm not well taught I get frightened because it goes with principles, guidelines you have to follow to get the formula or concept and once you don't have it you can't do it" (Participant B_E).

Among the participants in the control group, the following were their responses to the question, “Do you get frightened or scared when you are faced with questions involving the mole concept”? This was what one of the participants said in response to the question.

> “First I always get scared because of the topic, as I said the explanation, at times some teachers will come and teach the topic and they can’t even explain to you the student to understand because he can’t explain we don’t also develop interest in it, we see it to be difficult” (Participant A_C).

Yet another participant did indicate: “I get frightened because of little understanding, you have the fear that you might not be able to deliver to expectation and even when you try to do something, doubt comes” (Participant D_C).

To determine the attitude of the students toward the mole concept and chemistry in general, they were interviewed on the question: “What is influencing your like or dislike for the mole concept and chemistry in general”? ‘Participant C_E’ in the experimental group did respond as stated: “the calculation in mole concept is too much….it will reduce the pressure if we are taught well”. ‘Participant D_E’ also in the experimental group indicated: “is not easy for me to understand the mole concept and even the units are confusing because of ‘M’ for molar mass and again ‘M’ for concentration”. In the control group, responding to the same question, one of the participants stated:

> “My dislike is from the Senior High School where I didn’t have good teacher who could explain this topic into details for me to understand, but I will like it too and it will be an interesting subject to me if someone is there to explain it or if the chemistry teachers are taking that topic in particular…..” (Participant A_C).

‘Participant D_C’ stated: “the major factor is the poor background and the mentality of the thing being difficult”.

Inferring from the responses of the participants interviewed, it was clear that each of them had something different or similar to say regarding the perceptions and attitudes toward the mole concept. The interview results of the participants pointed to the fact that the mole concept is difficult and that there are too many calculations in the mole concept. These responses from the interview results reflected in some of the responses that the students indicated in the Likert scale-based questionnaires. The students prefer studying biology and its related areas to chemistry and its related areas. Some of the participants through the interview indicated that they usually get frightened or scared when faced with questions involving the mole concept and that they dislike the mole concept due to many calculations, confusing regarding the units used in the calculations and the poor background from the Senior High School level. These responses from the interview results also confirmed what the majority of the students indicated in the questionnaires claiming that the mole concept is confusing and scaring. Per the results of the interview, the students showed negative attitude and perception toward the mole concept before the treatment. Such attitude and perception exhibited by the students toward the mole concept reflected in their poor performance in the pre-test. It also reflected in the poor performance of the students in the post-test in the control group after they were exposed to the TLB.

The students' argument about the difficult nature of the mole concept conforms to a study by Polancos (2009), which contends that the mole concept is an area that very few students like and succeed at, and which most students hate and struggle with because of their dislike for mathematics. Dahsah and Coll (2007) also argue that the term carbon-12 atoms, causes some confusion among students owing to the fact that the numerical value (12) of the mass of the carbon atoms looks identical to the value of its molar mass. The fact that the mole is a concept, a unit of measurement and a number creates confusion and difficulty for many students studying it. The difficulty is normally aggravated when the teaching method is not appropriate. Particularly the TLB approach has proved less effective in aiding students to have better cognitive achievement in the mole concept as revealed by the study. Nonetheless, the PBL approach has proved more effective in assisting students to have better cognitive achievement in the mole concept.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Overview

This chapter presents the summary of findings, the conclusion based on the results of the study and recommendations for consideration by different interest groups in relation to the study.

5.2 Summary of Findings

The focus of the study was on the effect of problem-based learning on students' achievement in the mole concept. Test, Likert scale-based questionnaire and interview were the instruments designed and applied to find out the effect of problem-based learning on students' achievement in the mole concept. The research design was quasi-experimental which employed two intact classes, one serving as the experimental group (N= 44) and the other as the control group (N= 44). In all a sample size of eighty-eight participants were used for the study.

Related literature was reviewed on the concept of the mole and that of problem-based learning. Literature was also reviewed on the effect of problem-based learning on students' achievement in the mole concept. The findings of the study reveal that the students before the treatment had equivalent achievement in the mole concept per the scores of the pre-test administered. There was no significant difference between the achievement of the students in the mole concept in the control group and those in the experimental group before the treatment commenced. The results of the study also indicate that on the whole, the students in the problem-based learning class (experimental group) had better achievement in the mole concept than those in the traditional lecture-based class (control group). The students in the problem-based learning class showed positive perception and attitude toward the mole concept than those in the traditional lecture-based class although both classes indicated the difficulties associated with the learning of the mole concept prior to the treatment.

5.3 Conclusion

The study reveals that the problem-based learning has positive effect on the students' achievement in the mole concept as students in the problem-based learning class did significantly better than their counterparts in the traditional lecture-based class. The study actually confirms Hung (2008) study which asserts that problem-based learning appears to be the most innovative instructional method conceived and implemented in education with the aim of enhancing students' application of knowledge, problem solving skills, higher-order thinking, and self-directed learning skills. Thus in the context of this study problem-based learning remains one of the successful teaching strategies which directly supports Savery (2006), a study which opines that PBL is an instructional approach that has been used successfully for over 30 years and continues to gain acceptance in multiple disciplines.

Although in literature, a number of scholars re-emphasised the difficulties students encounter in learning the mole concept and the negative perception and attitude toward it, problem-based learning demystifies that kind of perception and attitude. The students' personal constructs in the area of perception and attitude were positively influenced by the problem-based learning.

5.4 Recommendations

Based on the results of the study, the following recommendations are made.

- Problem-based learning should be considered at the various stages of the integrated science curriculum design for Colleges of Education in Ghana - the planning stage, development and implementation stages.
- There should be a change among curriculum implementers (teachers and students) from the traditional lecture-based approach to teaching and learning which has proved less effective to innovative instructional approaches such as the problem-based learning which has proved more effective in various disciplines including science.
- With the already existing negative perceptions and attitudes of the Ghanaian student toward science which have adverse effect on their achievement, there is the need for student-centred pedagogies like problem-based learning to demystify the negative perception and attitude of students toward the learning of science.
- The findings of the study will serve as a useful document for policy planning and implementation in the education sector to the benefit of the Ghanaian populace.
- The study will serve as a useful document for the head of the institution and in his team in Tamale College of Education to improve the teaching of science in the college.

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APPENDICES

Appendix A: Pre-test

Pretest for College Students on Mole Concept

The purpose of this exercise is to obtain data for research only. It does not form part of students' continuous assessment for end of semester examination. The main objective is to find out your knowledge or understanding of the mole concept. Thus do well to approach all questions with open mind without copying from one another. All marks obtained on the test will be treated confidentially since you will not indicate your name on the test paper. The responses you give to the questions will guide science teachers in the college to plan their lessons well for effective teaching.

Thank you for your understanding and cooperation.

Biodata of Respondent

Kindly write your serial number, sex, age, programme, level, class and date in the spaces provided below.

Serial Number----------------- Programme-------------------------------- Level----------

Class----------

Sex ------------- Age ----------- Date ---------------------------

Instructions

This test comprises two sections; section A and section B. Answer all the questions in both sections. Section A contains multiple choice options with letters A-D where you need to circle the letter that indicates the correct answer. In section B, you need to write the answers in the spaces provided.

Time: 1 Hour 15 mins

SECTION A (10 marks)

1. The mole is

(a) an SI unit (b) a quantity of measurement (c) a number (d) a volume

2. The mole can be termed as the Avogadro's number. Which of the following is the Avogadro's number?

(a) 6.01 x 10^{23} (b) 6.01 x 10^{22} (c) 6.02 x 10^{22} (d) 6.02x 10^{23}

3. Avogadro's number represents the number of atoms in

(a) 12g of C-12 (b) 320g of sulphur (c) 32g of oxygen (d) 12.7g of iodine

4. The number of moles of carbon dioxide which contain 8g of oxygen is

(a) 0.5 mol (b) 0.20 mol (c) 0.40 mol (d) 0.25 mol

(C =12.0, O =16.0)

5. Which has maximum number of atoms?

(a) 24g of C (b) 56g of Fe (c) 27g of Al (d) 108g of Ag

(C=12, Fe=56, Al=27, Ag=108)

6. 2 moles of silicon tetrachloride, $SiCl_4$ contains

(a) 4 moles of chlorine atoms (b) 8 molecules of chlorine atoms (c) 8 moles of chlorine atoms (d) 6 moles of chlorine atoms

7. How many moles of Cu atoms are present in 3.05 g of copper (Cu = 63.5).

(a) 20.8 mol (b) 0.048 mol (c) 193.7 mol (d) 0.50 mol

8. In what unit is molar mass measured?

(a) g/mol (b) M (c) g/dm^3 (d) mol/dm^3

9. 1 amu is equal to

(a) 1.66×10^{-23} kg (b) 1/14 of O-16(c) 1g of H_2 (d) 1/12 of C-12

10. 2.0 g of oxygen contains number of atoms same as in

(a) 4g of S (b) 7g of nitrogen (c) 0.5 g of H_2 (d) 12.3 g of Na.

(O =16.0, S =32.0, N =14.0, H =1.0, Na =23.0, L = 6.02 x10^{23})

SECTION B (20 marks)

Provide the answers for each question in the spaces given below.

1. Define the term mole of a substance --

--- **1 mark**

2. Explain which has more mass, 1 mole of oxygen molecule (O_2) or 1 mole of aluminium atoms (Al). (O=16, Al=27). **2 marks**

3. A sample of nitrogen gas consists of 4.22×10^{23} molecules of nitrogen. How many moles of nitrogen gas are there? ($L= 6.02 \times 10^{23}$). **2 marks**

4. What is molar volume?---

----

1 mark

5. How many grams of sodium hydroxide are needed to prepare0.25dm^3 of 2M solution of NaOH? (Na=23, O=16, H=1). **3 marks**

6. Explain the term molar mass--

---**2 marks**

7. Calculate the mass of $NaNO_3$ needed to prepare 0.025 moldm^{-3}solution using a 1.0 dm^3 volumetric flask.(Na = 23.0, N = 14.0, O = 16.0). **3 marks**

8. There are 3.010×10^{23} particles per mole of CO_2 gas. What amount of CO_2 gas is present? ($L = 6.02 \times 10^{23}$, $C = 12.0$, $O = 16.0$). **2 marks**

9. Calculate the amount of substance (mole) in 2.8 dm^3 of CO_2at s.t.p. ($V_m = 22.4$ dm^3/mol). **2 marks**

10. Calculate the molar mass of 0.05 moles of Sulphur (IV) oxide gas which has a mass of 2.5g. **2 marks**

Appendix B: Post-test

Post-Test for College Students on Mole Concept

The purpose of this exercise is to obtain data for research only. It does not form part of students' continuous assessment for end of semester examination. The main objective is to find out your knowledge or understanding of the mole concept. Thus do well to approach all questions with open mind without copying from one another. All marks obtained on the test will be treated confidentially since you will not indicate your name on the test paper. The responses you give to the questions will guide science teachers in the college to plan their lessons well for effective teaching.

Thank you for your understanding and cooperation.

Biodata of Respondent

Kindly write your serial number, sex, age, programme, level, class and date in the spaces provided below.

Serial Number---------------- Programme------------------------------ Level---------

Class----------

Sex ------------- Age ---------- Date ---------------------------

Instructions

This test comprises two sections; section A and section B. Answer all the questions in both sections. Section A contains multiple choice options with letters A-D where you need to circle the letter that indicates the correct answer. In section B, you need to write the answers in the spaces provided.

Time: 1 Hour 15 mins

SECTION A (10 marks)

1. What is the molar mass of $Mg(OH)_2$? (Mg =24, O =16, H =1)

(b) 41g/mol (b) 58g/mol (c) 384g/mol (d) 24g/mol

2. The amount of substance is measured in

a. grams (b)atoms or molecules (c) moles (d) grams per mole

3. The mass in grams of one mole of any pure substance is called its ____ mass.

a. atomic (b) formula (c) molecular (d) molar

4. How many atoms are in 0.05 mol of sodium?

a. 1.204×10^{25} (b) 3.01×10^{23} (c) 1.204×10^{23} (d) 3.01×10^{22}

($L = 6.02 \times 10^{23}$)

5. Which of the following is correct option? 1.0 mole of NH_3 (ammonia) contains

I. 6.02×10^{23} molecules

II. 4 mol of atoms

III. 1 mol of nitrogen atoms

IV. $3 \times 6.02 \times 10^{23}$

a. I only (b) II and III only (c) I, II and IV only (d) I, II, III and IV

6. 2 moles of carbon (IV) oxide, CO_2 contains

a. 4 moles of carbon atoms (b) 4 moles of oxygen atoms (c) 4 moles of oxygen molecules (d) 2 moles of carbon molecules

7. 1 mol of hydrogen molecule (H_2) reacts with 1 mol of fluorine molecule (F_2) to yield 2 mol of hydrogen fluoride (HF). If the HF contains 2.5 mol, how many moles of the fluorine molecule (F_2) reacted?

a. 1.0mol (b) 2.0 mol (c) 1.25 mol (d) 5.0mol

8. What are the respective units for measuring the following quantities as expressed in the mole concept; mass, molar mass and amount of substance?

a. gram, gram per mole and mole (b) gram per mole, mole and gram (c) gram, mole and gram per mole (d) gram per mole, gram and mole

9. There are 6.02×10^{23} atoms in one ____ of atoms.

a. newton (b) mole (c) amu (d) kilogram

10. Calculate the mass of $NaNO_3$ needed to prepare 0.025 $moldm^{-3}$ solution using a $1.0dm^3$volumetric flask. (Na =23.0, N =14.0, O = 16.0)

a. 85.0 g (b) 2.500g (c) 40.0g (d) 2.125g.

SECTION B (20 marks)

Provide the answers for each question in the spaces given below. Show working where there are calculations.

1. What is the mathematical relationship between the Avogadro's constant, the number of particles and the amount of substance (mole)?

----

1 mark

2. A substance W has a concentration of 0.02mol when its molar mass was found to be 74.0gmol^{-1}. Another substance V contains 1.00 x 10^{23} atoms and has a molar mass of 40.0gmol^{-1}. Which of the two substances has the greater mass (in grams)? (Show by working) (L= 6.02 x 10^{23}). **3 marks**

3. A sample of sulphur gas consists of 5.22 x 10^{23} molecules of sulphur. How many moles of sulphur gas are there? (L= 6.02 x 10^{23}). **2 marks**

4. Define the term mole of a substance?---

--------------------------- **1 mark**

5. What mass of $CaCO_3$ is needed to prepare $0.3dm^3$ of 2 $moldm^{-3}$ solution of $CaCO_3$? (Ca= 40, C= 12, O=16). **3 marks**

6. (a) Define the term molar mass ---

------------------------------- **1 mark**

(b) Find the molar mass of $Ca(OH)_2$. (Ca= 40, O= 16, H= 1). **1 mark**

7. Determine the number of atoms in 0.4 mol of chlorine molecules ($L = 6.02 \times 10^{23}$). **2 marks**

8. Calculate the amount of nitrogen dioxide gas in 2.107 x 10^{23} molecules of the gas. (L= 6.02 x 10^{23}). **2 marks**

9. What volume of CO_2 at standard temperature and pressure (s.t.p) contains 0.125 moles of the gas? (Vm = 22.4 dm^3/mol). **2 marks**

10. What do the following symbols stand for in formulae relating to the mole concept? **2 marks**

a. **N** --

b. **L** --

c. **n** --

d. **M** --

Appendix C: Interview Schedules

Semi-Structured Interview Schedules for the Students on Mole Concept

The purpose of this interview is to seek your perceptions and attitudes toward the mole concept and the responses you provide are for research and academic use only. Please as much as possible indicate your honest responses to all questions. Confidentiality to every piece of information you provide is assured.

Thank you for your time and co-operation

Items in the Interview Schedule

1. Please introduce yourself briefly; your name, class, age and programme you are doing in the college.
2. Which of these three aspects in the Senior High School integrated science do you like most; chemistry, biology and physics?
3. Please give reason(s) for your like and/or dislike
4. Will you like to continue with science courses particularly chemistry or if you have the opportunity you will drop it?
5. Which of the following topics in the chemistry aspect of integrated science do you find difficult to understand? (I) Bonding (II) Mixtures (III) Compounds (IV) Mole Concept (V) Atomic Structure
6. Is the mole concept difficult or easy?
7. Do you like a lot of calculation subjects like chemistry?
8. Do you do well in mole concept exercises, assignments and tests?
9. Do you get frightened or scared when you are faced with questions involving the mole concept?

10. What is influencing your like or dislike for the mole concept and chemistry in general?

Appendix D: Questionnaire

Mole Concept Perception and Attitude Scale (MCPAS)

This questionnaire seeks to measure students' perceptions and attitudes toward the mole concept. Please complete the questionnaire with all honesty. Read each statement and indicate your response by putting a tick (✓) inside one of the columns below to indicate your choice of the five options. The purpose of this questionnaire is for research and academic use only. Your responses will be treated with confidentiality.

Thank you for your time and co-operation.

Section A: Respondent's Biodata

Name of College ☐

Programme ☐

Gender: Male ☐ Female ☐

Age Range: 15 – 20 yrs ☐ 21-26 yrs ☐ 27 – 32 yrs ☐ 33- 38 yrs ☐

Level ☐

Section B: Students' Perceptions and Attitudes toward the Mole Concept

Please tick your response in the boxes corresponding to each statement using the key below to indicate your perception and attitude toward the mole concept. Your thoughtful and truthful responses are highly appreciated.

KEY

SA – Strongly Agree **A** – Agree **U** – Undecided **D** – Disagree **SD** – Strongly Disagree

No	Statement	SA	A	U	D	SD
1	Chemistry is a difficult subject					
2	The mole concept is easy					
3	I am comfortable learning the mole concept					
4	There are too many calculations in the mole concept					
5	Chemistry is satisfying					
6	The mole concept is well taught at the senior high school level					
7	I wish I did not have to take chemistry as a course					
8	I can do well in mole concept exams					
9	The mole concept is for pure science students					
10	Understanding the mole concept needs chemistry background					
11	I enjoy solving problems relating to the mole concept					
12	The terms used in the mole concept are scaring					
13	Mole concept lessons are boring					
14	The mole concept is needed to learn other chemistry topics					
15	The mole concept is confusing					
16	I do well in other subjects than chemistry					
17	I easily understand the symbols and units used in the mole concept					
18	The mole concept is not practical					
19	I do not understand what the mole concept is all about					
20	I like chemistry because of my career					

Appendix E: Procedure for Calculating Reliability Coefficient using Kuder-Richardson 20 (KR20) formula

The reliability coefficients of the pilot- tested instruments (pre-test and post-test) were determined using the Kuder-Richardson 20 (KR20) formula. The procedure for determining the KR20 is indicated below:

$$KR20 = \frac{N}{N-1}\left(1 - \frac{\Sigma (p_i q_i)}{\sigma^2}\right)$$

Where:
N = number of test items

pi = proportion answering item i correctly

qi = proportion answering item i incorrectly

σ2= variance of the test (raw scores).

Appendix F: Reliability Statistics

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.851	.857	20

Appendix G: Unpaired t-test Analysis of Pre-test Scores

t-Test: Two-Sample Assuming Equal Variances

	Pre-test (Experimental)	*Pre-test (Control)*
Mean	9.329545455	9.5
Variance	25.42957188	27.27906977
Observations	44	44
Pooled Variance	26.35432082	
Hypothesized Mean Difference	0	
Df	86	
t Stat	0.155737792	
P(T<=t) one-tail	0.438302342	
t Critical one-tail	1.66276545	
P(T<=t) two-tail	0.876604684	
t Critical two-tail	1.987934166	

Appendix H: Unpaired t-test Analysis of Post-test Scores

t-Test: Two-Sample Assuming Equal Variances

	post-test (Experimental)	*Post-test (Control)*
Mean	23.68181818	12.67045455
Variance	14.00105708	40.18538584
Observations	44	44
Pooled Variance	27.09322146	
Hypothesized Mean Difference	0	
Df	86	
t Stat	9.922523174	
P(T<=t) one-tail	3.2697E-16	
t Critical one-tail	1.66276545	
P(T<=t) two-tail	6.53941E-16	
t Critical two-tail	1.987934166	

Appendix I: Paired t-test Analysis of Pre-test and Post-test Scores in the Experimental Group

t-Test: Paired Two Sample for Means

	Pre-test (Experimental)	*post-test (Experimental)*
Mean	9.329545455	23.68181818
Variance	25.42957188	14.00105708
Observations	44	44
Pearson Correlation	0.221371095	
Hypothesized Mean Difference	0	
Df	43	
t Stat	17.07776064	
P(T<=t) one-tail	4.47688E-21	
t Critical one-tail	1.681070704	
P(T<=t) two-tail	8.95375E-21	
t Critical two-tail	2.016692173	

Appendix J: Paired t-test Analysis of Pre-test and Post-test Scores in the Experimental Group

t-Test: Paired Two Sample for Means

	Pre-test (Control)	*Post-test (Control)*
Mean	9.5	12.67045455
Variance	27.27906977	40.18538584
Observations	44	44
Pearson Correlation	0.070942105	
Hypothesized Mean Difference	0	
Df	43	
t Stat	2.654501289	
P(T<=t) one-tail	0.005545182	
t Critical one-tail	1.681070704	
P(T<=t) two-tail	0.011090363	
t Critical two-tail	2.016692173	

Appendix K: Unpaired Samples t-test of the Students' Perception and Attitude Scores in Experimental and Control Groups

t-Test: Two-Sample Assuming
Equal Variances

	POSTMCPAS (Experimental)	*POSTMCPAS (Control)*
Mean	69.43181818	54.70454545
Variance	83.87896406	115.3757928
Observations	44	44
Pooled Variance	99.62737844	
Hypothesized Mean Difference	0	
Df	86	
t Stat	6.920609085	
P(T<=t) one-tail	3.79985E-10	
t Critical one-tail	1.66276545	
P(T<=t) two-tail	7.59971E-10	
t Critical two-tail	1.987934166	

Appendix L：Scores of Pre-test in Control and Experimental Groups

Pre-test Scores in Control Group		Pre-test Scores in Experimental Group	
Serial Number	**Score (30)**	**Serial Number**	**Score (30)**
1	3.0	1	1.0
2	12.0	2	10.5
3	20.0	3	8.0
4	9.5	4	11.0
5	11.0	5	9.0
6	9.0	6	14.5
7	7.5	7	10.0
8	20.5	8	8.5
9	5.0	9	2.0
10	11.5	10	15.5
11	11.5	11	10.0
12	4.0	12	8.0
13	17.5	13	9.0
14	8.5	14	4.0
15	20.0	15	7.5
16	3.5	16	12.0

17	8.5	17	4.5
18	6.0	18	6.0
19	10.5	19	16.5
20	5.5	20	10.5
21	18.0	21	4.0
22	4.0	22	8.5
23	6.0	23	6.5
24	12.0	24	14.0
25	8.5	25	12.0
26	11.5	26	5.5
27	7.0	27	4.5
28	11.5	28	5.0
29	3.0	29	20.0
30	17.0	30	15.0
31	6.5	31	5.5
32	4.5	32	8.0
33	5.5	33	4.5
34	5.0	34	8.5
35	19.5	35	4.5
36	16.0	36	11.5
37	5.5	37	2.5
38	8.0	38	6.0
39	4.0	39	20.0
40	3.5	40	21.0
41	6.0	41	9.0
42	6.0	42	4.5
43	15.0	43	13.5
44	10.0	44	18.5

Appendix M: Scores of Post-test in Control and Experimental Groups

Post-test Scores in Control Group		Post-test Scores in Experimental Group	
Serial Number	**Score (30)**	**Serial Number**	**Score (30)**
1	15.0	1	25.0
2	12.5	2	23.0
3	23.5	3	19.0
4	9.0	4	24.0
5	5.0	5	19.5
6	18.0	6	26.0
7	18.5	7	26.0

8	16.0	8	21.5
9	7.5	9	25.0
10	12.0	10	29.0
11	3.5	11	26.0
12	8.0	12	26.0
13	17.5	13	27.5
14	15.5	14	14.5
15	19.5	15	23.5
16	8.5	16	26.5
17	12.0	17	17.0
18	5.0	18	26.0
19	22.0	19	25.0
20	6.0	20	23.0
21	13.5	21	18.5
22	13.5	22	24.5
23	10.0	23	19.5
24	5.0	24	28.0
25	6.0	25	24.0
26	17.0	26	24.0
27	19.5	27	16.0
28	12.0	28	25.5
29	4.0	29	25.0
30	7.5	30	13.0
31	16.5	31	26.0
32	23.0	32	27.5
33	10.0	33	26.0
34	11.0	34	21.5
35	13.0	35	20.0
36	7.5	36	26.0
37	18.5	37	24.0
38	11.5	38	28.0
39	3.5	39	26.0
40	24.0	40	25.0
41	18.5	41	25.5
42	27.0	42	25.5
43	3.0	43	28.0
44	8.0	44	22.0

Appendix N: Students Responses Based on the Pre-test

PRETEST FOR COLLEGE STUDENTS ON MOLE CONCEPT

The purpose of this exercise is to obtain data for research only. It does not form part of students' continuous assessment for end of semester examination. The main objective is to find out your knowledge or understanding of the mole concept. Thus do well to approach all questions with open mind without copying from one another. All marks obtained on the test will be treated confidentially since you will not indicate your name on the test paper. The responses you give to the questions will guide science teachers in the college to plan their lessons well for effective teaching.

Thank you for your understanding and cooperation.

BIODATA OF RESPONDENT

Kindly write your serial number, sex, age, programme, level, class and date in the spaces provided below.

Serial Number---42--------- **Programme** ---General---------- **Level**---100---- **Class**---A-----

Sex ---F------- **Age** ---21------ **Date** ---23/10/2013-----

INSTRUCTIONS

This test comprises two sections; section A and section B. Answer all the questions in both sections. Section A contains multiple choice options with letters A-D where you need to circle the letter that indicates the correct answer. In section B, you need to write the answers in the spaces provided.

Time: 1 Hour 15 mins

SECTION A **(10 marks)**

1. The mole is
   (a) an SI unit (b) a quantity of measurement (c) a number (d) a volume
2. The mole can be termed as the Avogadro's number. Which of the following is the Avogadro's number?
   (a) 6.01 x 10^{23} (b) 6.01 x [illegible] 10^{22} (d) 6.02x 10^{23}

3. Avogadro's number represents the number of atoms in

(a) 12g of C-12 (b) 320g of sulphur (c) 32g of oxygen (d) 12.7g of iodine

4. The number of moles of carbon dioxide which contain 8g of oxygen is

(a) 0.5 mol (b) 0.20 mol (c) 0.40 mol (d) 0.25 mol

(C =12.0, O =16.0)

5. Which has maximum number of atoms?

(a) 24g of C (b) 56g of Fe (c) 27g of Al (d) 108g of Ag

(C =12, Fe =56, Al =27, Ag =108)

6. 2 moles of silicon tetrachloride, $SiCl_4$ contains

(a) 4 moles of chlorine atoms (b) 8 molecules of chlorine atoms (c) 8 moles of chlorine atoms (d) 6 moles of chlorine atoms

7. How many moles of Cu atoms are present in 3.05 g of copper (Cu = 63.5).

(a) 20.8 mol (b) 0.048 mol (c) 193.7 mol (d) 0.50 mol

8. In what unit is molar mass measured?

(a) g/mol (b) M (c) g/dm^3 (d) mol/dm^3

9. 1 amu is equal to

(a) 1.66×10^{-23} kg (b) 1/14 of O-16 (c) 1g of H_2 (d) 1/12 of C-12

10. 2.0 g of oxygen contains number of atoms same as in

(a) 4g of S (b) 7g of nitrogen (c) 0.5 g of H_2 (d) 12.3 g of Na.

(O =16.0, S =32.0, N =14.0, H =1.0, Na =23.0, L = 6.02×10^{23})

3/20

SECTION B **(20 marks)**

Provide the answers for each question in the spaces given below.

1. Define the term mole of a substance ~~is the the mole of Substance is called~~ mole of Substance is defined as the mass of Substance Containing the same number of fundamental units ~~as~~

0

1 mark

2. Explain which has more mass, 1 mole of oxygen molecule (O_2) or 1 mole of aluminium atoms (Al). (O =16, Al= 27). **2 marks**

1 mole of atom or element contain 6.02×10^{23}

∴ 2 mole of atom or element (oxygen) $= 6.02 \times 10^{23} \times 2 = 12.04 \times 10^{23}$

0

3. A sample of nitrogen gas consists of 4.22×10^{23} molecules of nitrogen. How many moles of nitrogen gas are there? (L= 6.02×10^{23}). **2 marks**

Solution

nitrogen gas $= 4.22 \times 10^{23}$ $= 4.22 \times 10^{23}$

nitrogen gas $= L = 6.02 \times 10^{23} = 60.2$

0

4. What is molar volume? Is the volume occupied by one mole of a substance chemical element or chemical compound at a given temperature and pressure. It is equal to the molar (M) divided by the mass density.

1 mark

5. How many grams of sodium hydroxide are needed to prepare $0.25dm^3$ of 2M solution of NaOH? (Na =23, O =16, H =1). **3 marks**

molar mass = (1×23)+(1×16)+(1×1)
= 23 + 16 + 1
= 40g/mol

6. Explain the term molar mass Is a physical property defined as the mass of a ~~substance~~ given substance (chemical element or chemical compound) divided by it is amount of substance base SI unit for molar mass is kg/mol

2 marks

7. Calculate the mass of $NaNO_3$ needed to prepare 0.025 moldm^{-3} solution using a 1.0 dm^3 volumetric flask. (Na = 23.0, N = 14.0, O = 16.0) **3 marks**

$n = \frac{m}{M}$

$M = (1 \times 23) + (1 \times 14) + (16 \times 3)$

$23 + 14 + 48$

85 mol

$m = 0.025$ moldm^{-3}

$= \frac{0.025}{85}$

$n = 1/3400$ $n = 0.00029$.

8. There are 3.010×10^{23} particles per mole of CO_2 gas. What amount of CO_2 gas is present? ($L = 6.02 \times 10^{23}$, C = 12.0, O = 16.0) **2 marks**

mola mass $(1 \times 12) + (16 \times 2)$

= 44 mol.

0

9. Calculate the amount of substance (mole) in 2.8 dm^3 of CO_2 at s.t.p. (Vm = 22.4 dm^3/mol).

2 marks

mole = 2.8 dm^3

$\frac{2.8}{2.4}$ = 1.166 mole

0

10. Calculate the molar mass of 0.05 moles of Sulphur (IV) oxide gas which has a mass of 2.5g. **2 marks**

moles 0.05.

Mass 2.5g.

= 0.125.

0

11/30

PRETEST FOR COLLEGE STUDENTS ON MOLE CONCEPT

The purpose of this exercise is to obtain data for research only. It does not form part of students' continuous assessment for end of semester examination. The main objective is to find out your knowledge or understanding of the mole concept. Thus do well to approach all questions with open mind without copying from one another. All marks obtained on the test will be treated confidentially since you will not indicate your name on the test paper. The responses you give to the questions will guide science teachers in the college to plan their lessons well for effective teaching.

Thank you for your understanding and cooperation.

BIODATA OF RESPONDENT

Kindly write your serial number, sex, age, programme, level, class and date in the spaces provided below.

Serial Number---4--- **Programme** ---General--- **Level**---100--- **Class**---1K---

Sex ---Female--- **Age** ---21--- **Date** ---23/11/15---

INSTRUCTIONS

This test comprises two sections; section A and section B. Answer all the questions in both sections. Section A contains multiple choice options with letters A-D where you need to circle the letter that indicates the correct answer. In section B, you need to write the answers in the spaces provided.

Time: 1 Hour 15 mins

SECTION A **(10 marks)** 5/10

1. The mole is
   (a) an SI unit (b) a quantity of measurement (c) a number (d) a volume
2. The mole can be termed as the Avogadro's number. Which of the following is the Avogadro's number?
   (a) 6.01×10^{23} (b) 6.01×10^{22} (c) 6.02×10^{22} (d) 6.02×10^{23}

3. Avogadro's number represents the number of atoms in

   (a) 12g of C-12 (b) 320g of sulphur (c) 32g of oxygen (d) 12.7g of iodine

4. The number of moles of carbon dioxide which contain 8g of oxygen is

   (a) 0.5 mol (b) 0.20 mol (c) 0.40 mol (d) 0.25 mol

   (C =12.0, O =16.0)

28g

5. Which has maximum number of atoms?

   M = 1xn

   (a) 24g of C (b) 56g of Fe (c) 27g of Al (d) 108g of Ag

   (C =12, Fe =56, Al =27, Ag =108)

6. 2 moles of silicon tetrachloride, $SiCl_4$ contains

   (a) 4 moles of chlorine atoms (b) 8 molecules of chlorine atoms (c) 8 moles of chlorine atoms (d) 6 moles of chlorine atoms

7. How many moles of Cu atoms are present in 3.05 g of copper (Cu = 63.5).

   (a) 20.8 mol (b) 0.048 mol (c) 193.7 mol (d) 0.50 mol

8. In what unit is molar mass measured?

   (a) g/mol (b) M (c) g/dm^3 (d) mol/dm^3

9. 1 amu is equal to

   (a) 1.66×10^{-23} kg (b) 1/14 of O-16 (c) 1g of H_2 (d) 1/12 of C-12

10. 2.0 g of oxygen contains number of atoms same as in

    (a) 4g of S (b) 7g of nitrogen (c) 0.5 g of H_2 (d) 12.3 g of Na.

    (O =16.0, S =32.0, N =14.0, H =1.0, Na =23.0, L = 6.02×10^{23})

6/23

SECTION B (20 marks)

Provide the answers for each question in the spaces given below.

1. Define the term mole of a substance The mole of a substance refers to number of atoms in ~~12~~ 1/12 of carbon-12.

0

1 mark

2. Explain which has more mass, 1 mole of oxygen molecule (O_2) or 1 mole of aluminium atoms (Al). (O =16, Al= 27). **2 marks**

(i) = 1 mole of Oxygen molecule (O_2)
= where (O=16)
= 16×2 (2 since the oxygen molecules are 2)
= 32g

(ii) = 1 mole of aluminium atom
= where (Al = 27)
= 27g

So therefore it can be explained that oxygen has more mass.

2

3. A sample of nitrogen gas consists of 4.22 x 10^{23} molecules of nitrogen. How many moles of nitrogen gas are there? (L= 6.02 x 10^{23}). **2 marks**

= Nitrogen gas consists of 4.22×10^{23}
= where the avogadro's content (L) = 6.02×10^{23}
= N = L×n, where = N = number of ~~moles~~ molecules, L = constant and n is the number of ~~molecules~~ moles
= N = 4.22×10^{23}, L = 6.02×10^{23} = n = ?

$L \times \frac{N}{L} = \frac{L \times n}{L}$ ∴ ~~n = N/L = = n = 4.22 × 10^23~~

= n = L × N ∴ n = $6.02 \times 10^{23} \times 4.22 \times 10^{23}$ = 25.4044×10^{23}

0

4. What is molar volume? Molar volume refers to the volume of substance or particles contained in a mole.

1 mark

5. How many grams of sodium hydroxide are needed to prepare $0.25dm^3$ of 2M solution of NaOH? (Na =23, O =16, H =1). **3 marks**

= NaOH = 23 + 16 + 1 = 40g

= $\frac{n}{V}$ = 40g × 0.25dm³

= 10g

So =

= NaOH = 23 + 16 + 1 = 40g

= $\frac{0.25}{2}$ 0.25×2 = 0.5g

= $\frac{40g}{0.5g}$

∴ = 80g/dm³

6. Explain the term molar mass The term molar mass refers to the number of molecules in 1/12 of 1 molecule

2 marks

7. Calculate the mass of $NaNO_3$ needed to prepare 0.025 $moldm^{-3}$ solution using a 1.0 dm^3 volumetric flask. (Na = 23.0, N = 14.0, O = 16.0) **3 marks**

= $NaNO_3 = 23 + 3(14.0) + 3(16.0)$
$= 23 + 42 + 48$
$= 83g$
$= 83 \times 0.025$
$= 2.075g$

0

8. There are 3.010×10^{23} particles per mole of CO_2 gas. What amount of CO_2 gas is present? ($L = 6.02 \times 10^{23}$, C = 12.0, O = 16.0) **2 marks**

= $CO_2 = 2(12.0) + 2(16.0)$
$= 24 + 32$
$56g$
$= 56g \times 6.02 \times 10^{23}$
$= \frac{337.12 \times 10^{23}}{3.010 \times 10^{23}}$
$= 340.13$

0

9. Calculate the amount of substance (mole) in 2.8 dm^3 of CO_2 at s.t.p. ($Vm = 22.4\ dm^3/mol$).

2 marks

$$n = \frac{2.8\,dm^3}{22.4\,dm^3} = 0.125\,mol.$$

2

10. Calculate the molar mass of 0.05 moles of Sulphur (IV) oxide gas which has a mass of 2.5g. **2 marks**

$$N = \frac{m}{M} = M = \frac{2.5}{0.05} = \therefore 50g/dm^3$$

Appendix O: Students Responses Based on the Post - test

13/30

POST-TEST FOR COLLEGE STUDENTS ON MOLE CONCEPT

The purpose of this exercise is to obtain data for research only. It does not form part of students' continuous assessmentfor end of semester examination. The main objective is to find out your knowledge or understanding of the mole concept. Thus do well to approach all questions with open mind without copying from one another. All marks obtained on the test will be treated confidentially since you will not indicate your name on the test paper. The responses you give to the questions will guide science teachers in the college to plan their lessons well for effective teaching.

Thank you for your understanding and cooperation.

BIODATA OF RESPONDENT

Kindly write your serial number, sex, age, programme, level, class and date in the spaces provided below.

Serial Number--35-------- **Programme**--GENERAL---------- **Level**--100-- **Class**--A----

Sex FEMALE **Age** --22---- **Date** --19/01/2016--

INSTRUCTIONS

This test comprises two sections; section A and section B. Answer all the questions in both sections. Section A contains multiple choice options with letters A-Dwhere you need to circle the letter that indicates the correct answer. In section B, you need to write the answers in the spaces provided.

Time: 1 Hour 15 mins

SECTION A(10 marks)

6/10

1. What is the molar mass of $Mg(OH)_2$? (Mg =24, O =16, H =1)
   (a) 41g/mol (b) 58g/mol (c) 384g/mol (d) 24g/mol
2. The amount of substance is measured in
   (a) grams (b)atoms or molecules (c) moles (d) grams per mole
3. The mass in grams of one mole of any pure substance is called its ____ mass.
   (a) atomic (b) formula (c) molecular (d) molar

4. How many atoms are in 0.05 mol of sodium?

(a) 1.204×10^{25} (b) 3.01×10^{23} (c) 1.204×10^{23} (d) 3.01×10^{22}

($L = 6.02 \times 10^{23}$)

5. Which of the following is correct option? 1.0 mole of NH_3 (ammonia) contains

I. 6.02×10^{23} molecules

II. 4 mol of atoms

III. 1 mol of nitrogen atoms

IV. $3 \times 6.02 \times 10^{23}$

(a) I only (b) II and III only (c) I, II and IV only (d) I, II, III and IV

6. 2 moles of carbon (IV) oxide, CO_2 contains

(a) 4 moles of carbon atoms (b) 4 moles of oxygen atoms (c) 4 moles of oxygen molecules (d) 2 moles of carbon molecules

7. 1 mol of hydrogen molecule (H_2) reacts with 1 mol of fluorine molecule (F_2) to yield 2 mol of hydrogen fluoride (HF). If the HF contains 2.5 mol, how many moles of the fluorine molecule (F_2) reacted?

(a) 1.0mol (b) 2.0 mol (c) 1.25 mol (d) 5.0mol

8. What are the respective units for measuring the following quantities as expressed in the mole concept; mass, molar mass and amount of substance?

(a) gram, gram per mole and mole (b) gram per mole, mole and gram (c) gram, mole and gram per mole (d) gram per mole, gram and mole

9. There are 6.02×10^{23} atoms in one ____ of atoms.

(a) newton (b) mole (c) amu (d) kilogram

10. Calculate the mass of $NaNO_3$ needed to prepare 0.025 $moldm^{-3}$ solution using a $1.0dm^3$volumetric flask. (Na =23.0, N =14.0, O = 16.0)

(a) 85.0 g (b) 2.500g (c) 40.0g (d) 2.125g.

7/20

SECTION B(20 marks)

Provide the answers for each question in the spaces given below.Show working where there are calculations.

1. What is the relationship between the Avogadro's constant, the number of particles and the amount of substance (mole)?

The relationship between Av

---1 mark

2. A substance W has a concentration of 0.02 mol when its molar mass was found to be $74.0gmol^{-1}$. Another substance V contains 1.00×10^{23} atoms and has a molar mass of $40.0gmol^{-1}$. Which of the two substances has the greater mass (in grams)? (Show by working) ($L= 6.02 \times 10^{23}$).**3 marks**

A

$C = 0.02$

$M = 74.00$

But $C = \frac{m}{M}$

$0.02 = \frac{m}{74.00}$

$m = 1.48g$ (1)

B

$N = 1.00 \times 10^{23}$

$M \cdot 40.0$

But $N = L \times C \Rightarrow C = L \times C$

$C = 1.00 \times 10^{23} \times 6.02 \times 10^{23}$

$C = 6.02$

$C = \frac{m}{M}$

$6.02 = \frac{m}{40.0}$

$\therefore m = 240.8$

Substance B has a greater mass than A.

3. A sample of sulphur gas consists of 5.22×10^{23} molecules of sulphur. How many moles of sulphur gas are there? ($L= 6.02 \times 10^{23}$).**2 marks**

$n = L \times C$

$n = 5.22 \times 10^{23} \times 6.02 \times 10^{23} = 31.4 mol^{-1}$

4. Define the term mole of a substance? It is the amount of substance that contain as many elementry entities as there are in 12 grams of carbon 12. (1)

1 mark

5. What mass of $CaCO_3$ is needed to prepare 0.3dm^3 of 2 moldm^{-3} solution of $CaCO_3$? (Ca= 40, C= 12, O=16). **3 marks**

$n = \frac{m}{M}$

$m = M \times n$ But $n = 0.3 \times 2 = 0.6$ (1) mols

molar mass $= (40 + 12 + 16) = 68$

$\therefore m = M \times n$

$m = 68 \times 0.6$

$m = 40.8$ grams

6. (a) Define the term molar mass It is the mass of an atom that contains as many atoms as there are in 1/12 grams of carbon 12.

1 mark

(b) Find the molar mass of $Ca(OH)_2$. (Ca= 40, O= 16, H= 1) **1 mark**

molar mass = M

$M = 40 + 16 + 1 = 57$ grams/mol

7. Determine the number of atoms in 0.4 mol of chlorine molecules ($L = 6.02 \times 10^{23}$)**2 marks**

Muber of Particles = Avogadro's Constant × mole

N = L × n N = $6.02 \times 10^{23} \times 0.4$

N = 2.408

8. Calculate the amount of nitrogen dioxide gas in 2.107×10^{23} molecules of the gas. ($L = 6.02 \times 10^{23}$)**2 marks**

$n = \frac{m}{M}$ or $n = \frac{L}{V}$ $n = \frac{6.02 \times 10^{23}}{2.107 \times 10^{23}}$

n = 2.86 mol

9. What volume of CO_2 at standard temperature and pressure (s.t.p) contains 0.125 moles of the gas? ($Vm = 22.4$ dm^3/mol).**2 marks**

$C = \frac{m}{V}$ $V = \frac{C}{n}$ $V = \frac{22.4}{0.125} = 2.8$ dm³

10. What do the following symbols stand for in formulae relating to the mole concept?**2 marks**

a. **N** Muber of Particles.
b. **L** Avogadro's Constant
c. **n** mole
d. **M** Molar mass

POST-TEST FOR COLLEGE STUDENTS ON MOLE CONCEPT

22/30

The purpose of this exercise is to obtain data for research only. It does not form part of students' continuous assessmentfor end of semester examination. The main objective is to find out your knowledge or understanding of the mole concept. Thus do well to approach all questions with open mind without copying from one another. All marks obtained on the test will be treated confidentially since you will not indicate your name on the test paper. The responses you give to the questions will guide science teachers in the college to plan their lessons well for effective teaching.

Thank you for your understanding and cooperation.

BIODATA OF RESPONDENT

Kindly write your serial number, sex, age, programme, level, class and date in the spaces provided below.

Serial Number--44-------- **Programme**---General class--- **Level**--100--- **Class**---1K---

Sex ---Male--- **Age** ---21--- **Date** ---18th-07-2016---

INSTRUCTIONS

This test comprises two sections; section A and section B. Answer all the questions in both sections. Section A contains multiple choice options with letters A-Dwhere you need to circle the letter that indicates the correct answer. In section B, you need to write the answers in the spaces provided.

Time: 1 Hour 15 mins

SECTION A(10 marks)

7/10

1. What is the molar mass of $Mg(OH)_2$? (Mg =24, O =16, H =1)
   (a) 41g/mol (b) 58g/mol (c) 384g/mol (d) 24g/mol
2. The amount of substance is measured in
   (a) grams (b)atoms or molecules (c) moles (d) grams per mole
3. The mass in grams of one mole of any pure substance is called its ____ mass.
   (a) atomic (b) formula (c) molecular (d) molar

4. How many atoms are in 0.05 mol of sodium?

   (a) 1.204×10^{25} (b) 3.01×10^{23} (c) 1.204×10^{23} (d) 3.01×10^{22}

   ($L = 6.02 \times 10^{23}$)

5. Which of the following is correct option? 1.0 mole of NH_3 (ammonia) contains

   I. 6.02×10^{23} molecules

   II. 4 mol of atoms

   III. 1 mol of nitrogen atoms

   IV. $3 \times 6.02 \times 10^{23}$

   (a) I only (b) II and III only (c) I, II and IV only (d) I, II, III and IV

6. 2 moles of carbon (IV) oxide, CO_2 contains

   (a) 4 moles of carbon atoms (b) 4 moles of oxygen atoms (c) 4 moles of oxygen molecules (d) 2 moles of carbon molecules

7. 1 mol of hydrogen molecule (H_2) reacts with 1 mol of fluorine molecule (F_2) to yield 2 mol of hydrogen fluoride (HF). If the HF contains 2.5 mol, how many moles of the fluorine molecule (F_2) reacted?

   (a) 1.0mol (b) 2.0 mol (c) 1.25 mol (d) 5.0mol

8. What are the respective units for measuring the following quantities as expressed in the mole concept; mass, molar mass and amount of substance?

   (a) gram, gram per mole and mole (b) gram per mole, mole and gram (c) gram, mole and gram per mole (d) gram per mole, gram and mole

9. There are 6.02×10^{23} atoms in one ____ of atoms.

   (a) newton (b) mole (c) amu (d) kilogram

10. Calculate the mass of $NaNO_3$ needed to prepare 0.025 moldm^{-3} solution using a 1.0dm^{3}volumetric flask. (Na =23.0, N =14.0, O = 16.0)

    (a) 85.0 g (b) 2.500g (c) 40.0g (d) 2.125g.

SECTION B(20 marks) 15/20

Provide the answers for each question in the spaces given below.Show working where there are calculations.

1. What is the relationship between the Avogadro's constant, the number of particles and the amount of substance (mole)?

   n = N/L (1) = N = Number of particles L = Avogadro's constant N = L × n = amount of substance
   L = N/n

   --1 mark

2. A substance W has a concentration of 0.02 mol when its molar mass was found to be 74.0gmol^{-1}. Another substance V contains 1.00 x 10^{23} atoms and has a molar mass of 40.0gmol^{-1}. Which of the two substances has the greater mass (in grams)? (Show by working) (L= 6.02 x 10^{23}).**3 marks**

   Substance (W)
   n = 0.02 moles
   M = 74.0 g/mol
   m = ?
   n = m/M
   n = m/M => m = n×M
   m = 0.02 × 74.0 g/mol
   m = 1.48g (1)

   Substance (V)
   N = 1.00 × 10^{23}
   M = 40.0 g/mol
   m = ?
   L = 6.02 × 10^{23}
   n(V) = N/L = n(V)
   1.00 × 10^{23} / 6.02 × 10^{23}
   => 1.67 mols

   But n(V) = n×M
   m(V) = 0.17 × 40
   6.8 g (1)
   The substance (V) has the greater mass than the substance (W)

3. A sample of sulphur gas consists of 5.22 x 10^{23} molecules of sulphur. How many moles of sulphur gas are there? (L= 6.02 x 10^{23}).**2 marks**

   N = 5.22 × 10^{23}
   L = 6.02 × 10^{23} (½)
   n = N/L = 0.867 mol (1)

4. Define the term mole of a substance?------ Is the amount of substance that contains so many particles

1 mark

5. What mass of $CaCO_3$ is needed to prepare0.3$dm^3$of 2 $moldm^{-3}$ solution of $CaCO_3$? (Ca= 40, C= 12, O=16).**3 marks**

C= 0.3 dm^3
V = 2 dm^3
n = C×V
= 0.3×2
= 0.6 ½

m Ca(CO3)
40+12+16(3)
40+12+48
= 100 ½

n = m/M = m = n×M = ½ 100×0.6
= 60 g/mol

6. (a) Define the term molar mass ------ The mass in gramm of a mole of a pure substance. (1)

1 mark

(b) Find the molar mass of $Ca(OH)_2$. (Ca= 40, O= 16, H= 1)**1 mark**

Ca(OH)2 = 40 + 16(2) + 1(2)
40 + 32 + 2
40 + 32 + 2
= 74 ½

7. Determine the number of atoms in 0.4 mol of chlorine molecules (L = 6.02 x 10^{23})**2 marks**

n = 0.4
L = 6.02 × 10^{23}

n = N/L = N = n × L
= 0.4 × 6.02 × 10^{23}
= 2.408 × 10^{23} mol

8. Calculate the amount of nitrogen dioxide gas in 2.107 x 10^{23} molecules of the gas. (L= 6.02 x 10^{23})**2 marks**

Amount = 2.107 × 10^{23}
L = 6.02 × 10^{23}

n = $\frac{2.107 \times 10^{23}}{6.02 \times 10^{23}}$ (1)
= 0.35 mol (1)

9. What volume of CO_2 at standard temperature and pressure (s.t.p) contains 0.125 moles of the gas? (Vm = 22.4 dm^3/mol).**2 marks**

V = ?
n = 0.125
vm = 22.4 dm^3/mol

n = V/Vm ⇒ V = n × Vm
= 0.125 × 22.4 dm^3 (1)
= 2.8 dm^3
∴ V = 2.8 dm^3 (1)

10. What do the following symbols stand for in formulae relating to the mole concept?**2 marks**

a. N ------Number of entity ½
b. L ------Avogadro's Constant ½
c. n ------Amount of Substance ½
d. M ------Molar Mass. ½

n = V/Vm = V = n × V