Journal of Education and Practice
ISSN 2222-1735 (Paper) ISSN 2222-288X (Online)
Vol.9, No.12, 2018

The Effectiveness of Problem-Based Learning Approach to Mole Concept among Students of Tamale College of Education

Boniface Yaayin
Department of Science Education, Tamale College of Education, P. O. Box 1 E/R, Tamale, Ghana
Tel: +223-208325794 E-mail: niberbon@yahoo.co.uk

Abstract
The purpose of the study was to determine the effectiveness of problem-based learning (PBL) approach to mole concept among students of Tamale College of Education**.** The study was quasi-experimental research and nonrandomized control group pre-test – post-test design. The total population considered for the study was 543 first year students of Tamale College of Education. The sample size was 88 first year students offering the General Programme. The selection procedure was nonrandomized. Intact or already existing classrooms were used for the study. The control group consisted of 44 first year students and the experimental group was equally 44 first year students as this arrangement was the prevailing situation in the two intact classes at the time the study was conducted. 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 instrument used in the study was the Mole Concept Achievement Test (MCAT) which took the form of pre-test and post-test. The reliability coefficients were found to be 0.736 and 0.751 for the pre-test and post-test respectively. Data were analysed using t-test and bar charts. The results of the study revealed that the PBL resulted in significantly higher students' achievement in mole concept than the TLB.
Keywords: General Programme, Achievement, Treatment, Experimental Group, Control Group

1. Introduction

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.

Chemistry is a very important subject, although students have difficulties studying it. 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 pure 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.

Regarding the difficult concepts in chemistry, the mole concept in particular is still a difficult area 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). In science, most of the concepts are interlinked and built on one another. To study one concept effectively, the foundation of another concept would have been laid for that to be possible. 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. For instance, a close examination of the definition of a mole of a substance creates problems for students. 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). This 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. Another scenario of the mole that confuses students is that this very mole is termed as a concept because its definition talks about the amount of matter; it is also referred to as a unit of measurement because in calculation there can be an expression like '0.50 mole' and finally it is expressed as a number such that one mole is equivalent to the Avogadro's number (6.02×10^{23}). Students' low achievement in the mole concept has a bearing on the confusion they face with the concept. 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 (Polancos, 2009). This situation has put researchers trying to find out teaching interventions that can improve students' achievement in the mole concept.

For sometimes now, the commonest approach to teaching science including the mole concept has been the traditional lecture-based (TLB) method. 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 mimic their acts without understanding whatever is taught. 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 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 revealed that the teaching method employed by a teacher reflects on students' understanding of the subject (Akinlaye, 1998). Other researchers are also of the view 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). 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. Problem solving strategies are learner-centred and are capable of making remarkable impact on instructional practices (Ogunyemi, 2010). Problem-based learning is a teaching method characterized by the use of problems or 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). 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.

The theoretical approach to this study was the constructivist theory. In the constructivist classroom, the teachers' role is to organize situations which will give way to the learners to hypothesize, predict, manipulate objects, pose questions, research, investigate and invent meanings relevant to what they are learning (Kibos, Wachanga & Changeiywo, 2015). A constructivist classroom is student centred that places emphasis 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).

The problem addressed by this study was that first year students offering the general programme in Tamale College of Education have difficulties in understanding the mole concept over the years. This was noticed by the researcher through his personal interaction with the students as a tutor in the College and close examination of 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. Students have problems in understanding and utilizing the mole concept in quantitative chemical problems (Bodner & Herron, 2002).

The purpose of the study was to find out the effectiveness of problem-based learning approach to mole concept among students of Tamale College of Education**.** The following research questions were addressed.

1. What is the difference in achievement of the students in the mole concept in the experimental and control groups before the treatments using PBL and TLB approaches respectively?
2. What is the difference in achievement of the students in the mole concept in the experimental and control groups after the treatments using the PBL and the TLB approaches respectively?

2. Methodology

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).

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 1). 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 group 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 1).

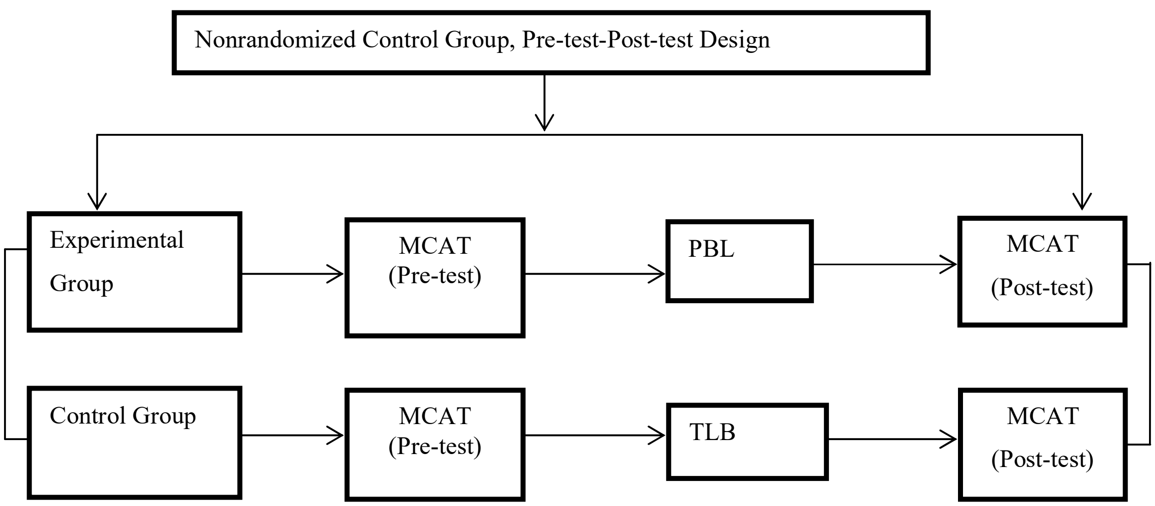

Figure 1. Nonrandomized Control Group Pre-test-Post-test Design (Ary, Jacobs & Razavieh, 2002)

The total population considered for the study was 543 first year students of Tamale College of Education. The sample size was 88 first year students offering the General Programme. The selection procedure was nonrandomized. Intact or already existing classrooms were used for the study. The control group consisted of 44 first year students and the experimental group was equally 44 first year students as this arrangement was the prevailing situation in the two intact classes at the time the study was conducted. To address the stated research questions, the sampling procedure therefore was purposive. 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 research instrument used for the study was the Mole Concept Achievement Test (MCAT). This took the form of pre-test and post-test. McMillan and Schumacher (1997) indicate that the term test refers to the use of test scores as data. This technique was used as the research participants' responded to written questions to measure their performance trait. A numerical value was obtained as a result of each participant's answers to a standard set of questions. The instrument was used as a way to determine the achievement of the participants.

Journal of Education and Practice www.iiste.org
ISSN 2222-1735 (Paper) ISSN 2222-288X (Online)
Vol.9, No.12, 2018

The reliability of the instrument was tested using first year students from Bagabaga College of Education which has similar characteristics to Tamale College of Education where the study was carried out. The reliability coefficients were found to be 0.736 and 0.751 for the pre-test and post-test respectively. The validity of the instrument was also ascertained as the test items were reviewed by experts. The data collection procedure is indicated as shown in Figure 2 below. The pre-test scores and the post-test scores formed the data for the study. The data were analysed with the help of SPSS version 20.0 and Microsoft Excel. The results were presented using bar charts and tables.

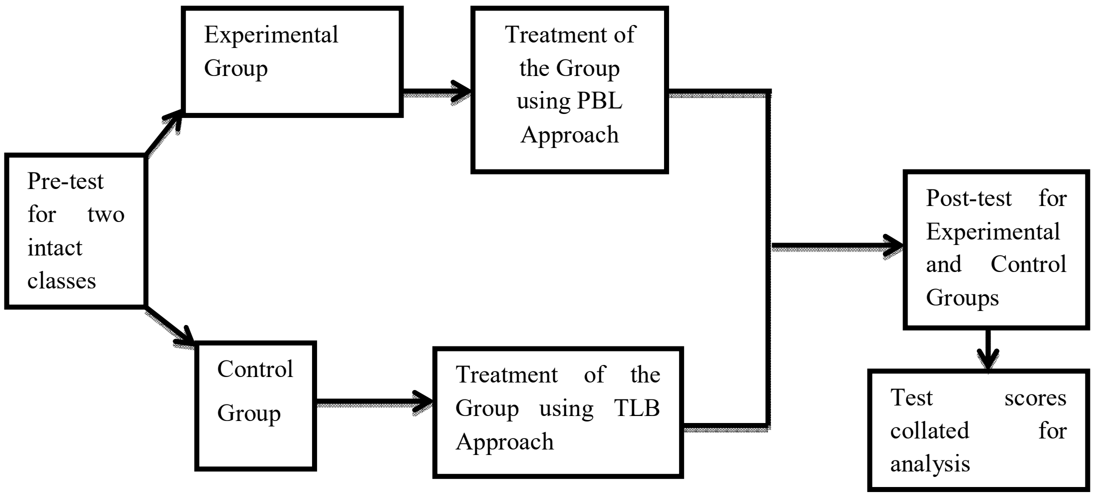

Figure 2. Data Collection Procedure for the Study

3. Results and Discussion

Research Question 1: What is the difference in achievement of the students in the mole concept in the experimental and control groups before the treatments using PBL and TLB approaches respectively?

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 was determined by using the students' pre-test scores. The pre-test was scored out of a total of thirty points in both the experimental and control groups. The pass mark (baseline) that determined whether a student failed or passed the test was fifteen. A student whose total score was below fifteen failed the test and those who scores were exactly fifteen or above passed the test. The results (Figure 3) revealed that ten and eleven students in the control and experimental groups respectively obtained total scores within the range of 1-5. Seventeen students in the control group and seventeen students in the experimental group had their total scores within the range of 6-10. Also nine students in the control group and ten students in the experimental group obtained total 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 in the control group and one student in the experimental group obtained a total score within a range of 21-30. The results showed 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 selected for the study obtained scores starting from one to fifteen. Just few students (fourteen), eight in the control group and six in the experimental group out of a total of eighty-eight students had scores above fifteen (Figure 3).

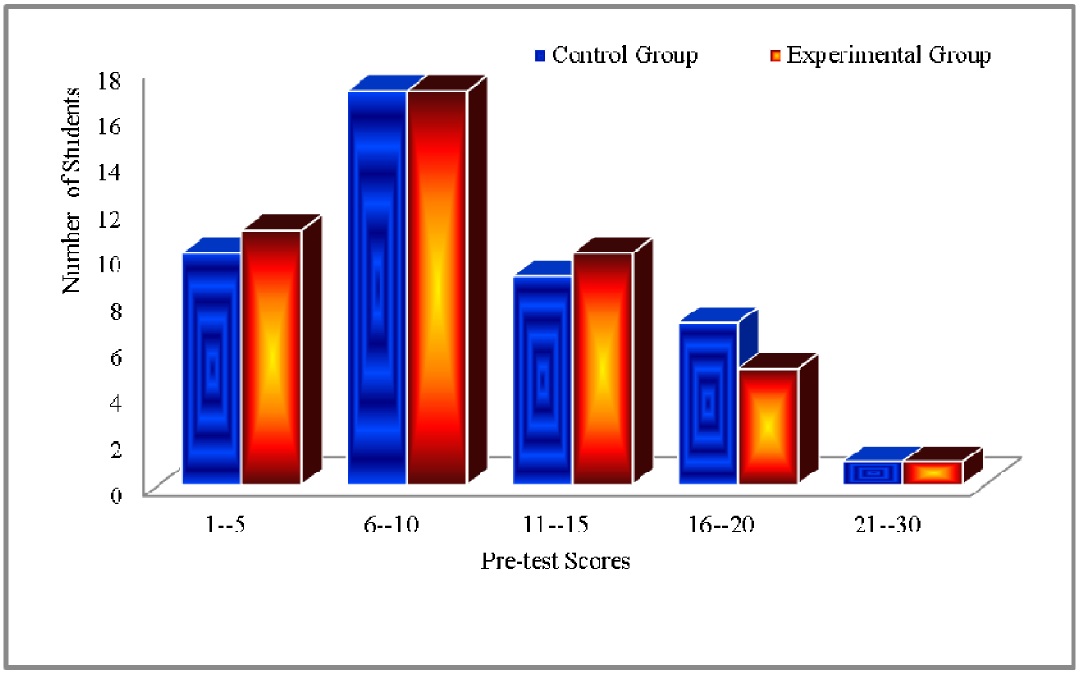

Figure 2. The Control and the Experimental Groups Pre-test Scores

The pre-test scores of both the experimental and control groups were compared using the unpaired t-test to find out if there was any significant difference between the achievements of the two groups in the mole concept. This is because the results presented using the chart does not tell the difference in achievement between the two groups even though a particular trend is being shown. The results (Table 1) revealed that there was no significant difference between the mean scores of the two groups (experimental and control) before the treatments using PBL and TLB approaches (p = 0. 877).

Table 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			

The fact that there was no significant difference between the two groups meant that the students' achievement in the mole concept before the treatments using PBL and TLB approaches was the same. Interestingly these were students drawn from various senior high schools across the country to Tamale College of Education, yet the study indicated that their level of achievement in the mole concept was the same. This meant that the students, irrespective of which senior high school they were coming from, had common difficulties in understanding the mole concept. The rather low achievement of the students in the mole concept at the pre-test level could be attributed to the abstract nature of the mole concept, hence the difficulties for the students to attain high achievement. The results of the study therefore support 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.

Apart from finding out whether there was any significant difference between the two groups in terms of the students' achievement in the mole concept base on their previous knowledge, the results of the study also formed the baseline for determining the effectiveness of the PBL approach on the students' achievement in the mole concept. The baseline in terms of achievement between the two groups was statistically the same. This therefore formed the basis for using the two groups as the experimental and the control groups.

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 low and that clearly indicated that they really had problems learning the mole concept.

Research question 2: what is the difference in achievement of the students in the mole concept in the experimental and control groups after the treatments using the PBL and the TLB approaches respectively?

This question aimed at comparing the achievement of the students in the mole concept using two teaching approaches (PBL and TLB). The main aim was 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), whereas in the control group seven, eleven and ten students obtained total test scores within the ranges of 1-5, 6-10 and 11-15 respectively, no student had a total score within the ranges of 1-5 and 6-10 in the experimental group. Only two students got their total scores within the range of 11-15. Eleven and seven students had their total scores within the range of 16-20 in the control and experimental groups respectively. On the other hand, as many as thirty-five students (out of a total of forty-four) obtained total scores within the range of 21-30 in the experimental group while in the control group only five students (out of a total of forty-four) had total scores within that same range. Comparatively, sixteen students obtained total scores above fifteen (the pass mark) in the control group, whilst as many as forty-two students got total scores above fifteen in the experimental group (Figure 4).

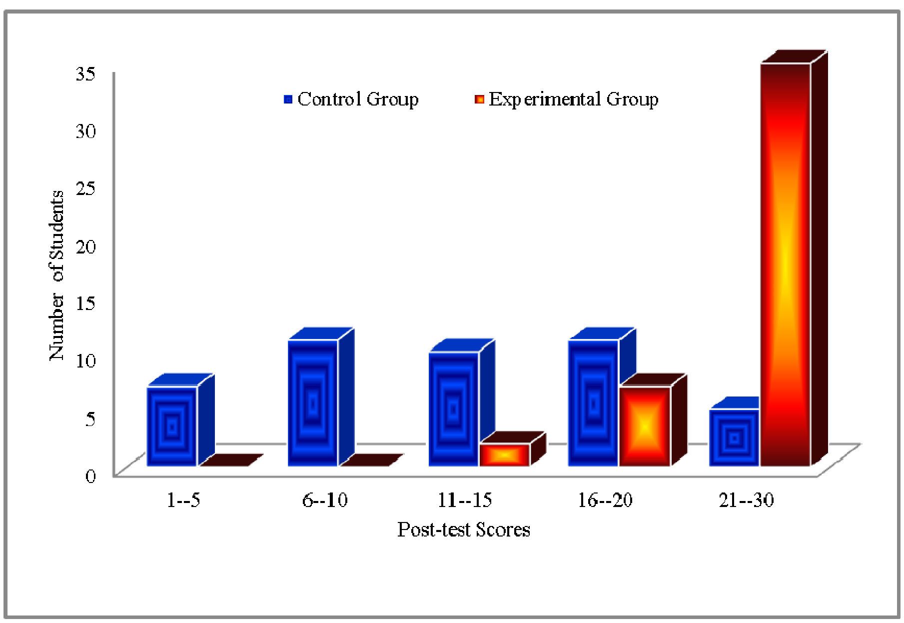

Figure 4. The Control and the Experimental Groups Post-test Scores

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 indicated 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 higher than the mean score of the control group (p = 0.000). The results revealed that the treatment using PBL yielded significantly higher achievement of students in the mole concept than the treatment using the TLB approach (Table 2).

Table 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			

Comparing the achievement of the students in the pre-test and post-test within the experimental group, the results (Figure 5) showed 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 (out of forty-four) obtained scores within that same range.

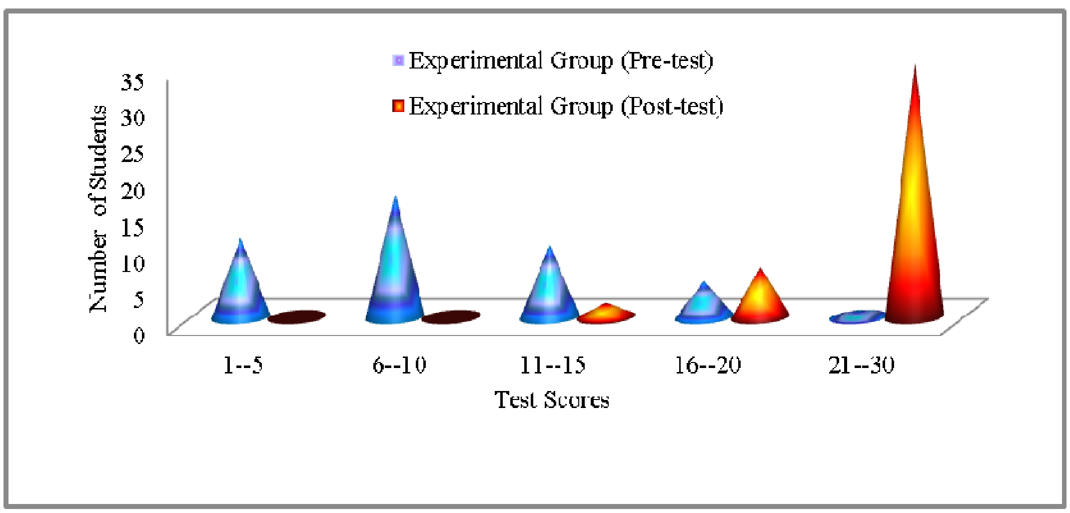

Figure 3. Pre-test and Post-test Scores in the Experimental Group

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 the same group. The results (Table 3) revealed 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 higher than the mean score of the pre-test (p = 0.000). The higher students' achievement in the post-test over the pre-test 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 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			

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) showed that there was a significant difference between the students' achievement in the mole concept using the post-test and that of the pre-test. The mean score of the post-test was significantly higher than the mean score of the pre-test (p = 0.011). This notwithstanding, 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. 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			

The results of the study in general revealed 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 showed 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). 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 supports 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 being taught.

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 confirms 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. Conclusion

First year General Programme students in Tamale College of Education perform better in mole concept when taught using problem-based learning approach. The results of this study revealed that the treatment using PBL yielded significantly higher achievement of students in the mole concept than the treatment using the TLB approach. In PBL, learning is carried out among students in small groups where there is sharing of ideas among group members in the form of discussion which creates room for all members to benefit from whatever is being discussed. Students construct their own meanings of the concepts learnt with high level of retention. Students are self-directed and acquired problem solving skills to learn among themselves with limited guidance by the teacher, who serves as a facilitator. This practice of PBL led to the students of Tamale College of Education obtaining higher achievement in the mole concept.

The long practiced teaching approach referred to as the traditional lecture-based method does not improve the achievement of the students in the mole concept as the study results indicated that the students had low achievement in the mole concept when taught with the TLB approach. With this approach, the teacher dominates in the teaching and learning process. Students are denied small group approach to learning and instead of students constructing their own meanings of concepts learnt, they are forced to memorise these concepts with limited or without understanding. Drawing conclusion from these two (PBL and TLB) perspectives of teaching approaches, the problem-based learning approach to the mole concept is therefore effective than the traditional lecture-based method.

Acknowledgment

The supervisor of my Master of Philosophy thesis from which this research paper has been developed is duly acknowledged for his effort and guidance. He is no less a person than Dr. J. Nana Annan. Again, I sincerely appreciate the direction and the coaching given to me by Dr. Julius Yirzagla to produce this paper. Finally, my profound gratitude goes to the Principal of Tamale College of Education, Dr. Sulemana Iddrisu for his continuous motivation that has resulted in the write up of this paper.

References

Ajelabi, P. A. (1998). "The relative effectiveness of computer assisted and text- assisted programmed instruction on students' learning outcomes in social studies", *Unpublished Ph. D. Thesis*, University of Ibadan.

Akar, H. (2005). *Effectiveness of 5E learning cycle model on students understanding of acid base concept.* Turkey: Middle East Technical University.

Akinlaye, F. A. (1998). "Teacher directed inquiry, guided discussion and students' learning outcomes in some aspects of social studies", *Unpublished Ph.D. Thesis,* University of Ibadan.

Ary, D., Jacobs, L. C., & Razavieh, A. (2002). *Introduction to Research in Education* (6^{th} ed.). USA: Wadsworth.

Bodner, G. M., & Herron, J. D. (2002). *Chemical Education: Towards Research-based Practice.*India:Kluwer Academic Publishers.

Brown, T. L., LeMay, H. E., Bursten, Jr. B. E., & Murphy, C. J. (2009). *Chemistry: The Central Science* (11^{th}ed.). Upper Saddle River, NJ: Prentice Hall.

Burke, A. (2011). Group work: how to use groups effectively. *The Journal of Effective Teaching*, 11(2), 87-95.

Case, J. M., & Fraser, D. M. (1999). An investigation into chemical engineering students' understanding of the mole and the use of concrete activities to promote conceptual change. *International Journal of Science Education*, 21(12), 1237–1249.

Chief Examiner's Report, Institute of Education, University of Cape Coast (2014). Colleges of Education-Three Year Diploma in Basic Education, First Year End of Second Semester Examination. Institute of Education, University of Cape Coast.

Coombs G., & Elden, M. (2004). Introduction to the special issue: Problem-Based Learning as social inquiry-PBL and management education, *Journal of Management Education,* 28, 523-535.

Dahsah, C., & Coll, R. K. (2007). Thai Grade 10 and 11 students' conceptual understanding and ability to solve stoichiometry problems. *Research in Science & Technological Education*, 25(2), 227-241.

Fatoke, A. O., & Olaoluwa, O. O. (2014). Enhancing students' attitude towards science through problem-solving instructional strategy. *IOSR Journal of Research & Method in Education (IOSR-JRME)* 4(5), 50-53.

Harper-Marinick, M. (2001). Engaging students in problem-based learning. Maricopa Centre for Learning and Instruction. [online] Available: http://www.mcli.dist.maricopa.edu/forum/spr01/t11.html

Hirca, N. (2011). Impact of problem-based learning to students and teachers. *Asia-Pacific Forum on Science Learning and Teaching,* 12(1), 1-19.

Hung, W. (2008). The 9-step problem design process for problem-based learning: Application of the 3C3R model. *Educational Research Review* 4 (2009), 118–141.

Kehinde, V. O. (2005). "The Effect of Problem-solving Instructional Strategies on Students' Learning Outcomes in the Mole Concept", *Unpublished M. Ed. Thesis*, University of Ado Ekiti, Nigeria.

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

Levy, Y., & Ellis, T. (2011). A guide for novice researchers on experimental and quasi-experimental studies in information systems research. *Interdisciplinary Journal of Information, Knowledge, and Management,* 6, 151-161.

McMillan, J. H., & Schumacher, S. (1997). *Research in education: A conceptual introduction* (4^{th} ed.). New York, NY: Longman.

Musa, U. (2009). Teaching the mole concept using a conceptual change method at college level. *Education,* 129(4), 683 – 691.

Njoku, Z. C. (2004). Fostering the application of science educational research findings in Nigeria classrooms: strategies and needs for teachers' professional development. In *M.A.G Akale (Ed.). 45th Annual Conference Proceedings of Science Teachers' Association of Nigeria,* Ibadan: HEBN Publishers P/C.

Nwachukwu, O. C. (2012). Revisiting science education and national development: Nigerian situation and the way forward. *Kuwait Chapter of Arabian Journal of Business and Management Review,* 1(10), 1.

Ogunyemi, O. O. (2010). "Wood's and OsborneParnes' problem-solving models and students' learning outcome in junior secondary school social studies*", Unpublished M. Ed. Dissertation,* Olabisi Onabanjo University, Ago-Iwoye.

Polancos, D. T. (2009). Effects of mathematics review on the learning of high school chemistry concept and on problem solving. *Liceo Journal of Higher Education Research*, 6 (1), 80- 99.

Raimi, S. M., & Adeoye, F. A. (2004). Problem based learning strategy and quantitative ability in college of education students' learning of integrated science. *Ilorin Journal of Education.*

Savery, J. R. (2006). Overview of Problem-based Learning: Definitions and Distinctions. *Interdisciplinary Journal of Problem-Based Learning,* 1(1), 9-20.
Shehu, G. (2015). The effect of problem-solving instructional strategies on s tudents' learning outcomes in senior secondary school chemistry. *IOSR Journal of Research and Method in Education (IOSR-JRME)* 5(1), 10-14.
Sirhan, G. (2007). Learning difficulties in chemistry: an overview. *Journal of Turkish Science Education,* 4(2), 2-20.
Teddlie, C., & Yu, F. (2007). Mixed methods sampling: a typology with examples. *Journal of Mixed Methods Research* 1(77), 76-100.
West, S. A. (1992). Problem based learning - A viable addition of senior secondary science. *Senior Science Research,* 73 (1), 265.