COMPARATIVE EFFECT OF PROBLEM-BASED LEARNING AND CONCEPT MAPPING TEACHING STRATEGIES OF SENIOR SECONDARY STUDENTS AND THEIR ACHIEVEMENTS IN CHEMISTRY

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Abstract

This study compared the effectiveness of problem-based learning and concept mapping on the academic achievement of students in Calabar Education Zone, Cross River State-Nigeria. A research question and a hypothesis were formulated to provide focus and to direct the study. The research design was a quasi-experimental factorial research design involving pre-test-post-test. The sampling technique was a simple random sampling technique. The sample comprised of 124 senior secondary school two chemistry students. The instrument for data collection was a 30-item Chemistry Achievement Test (CAT). The experimental group was taught using problem-based learning and concept mapping teaching strategies while the control group was taught using the conventional teaching method. The data obtained was analysed using analysis of covariance (ANCOVA). The result revealed that students taught thermochemistry using concept mapping performed best followed by those taught using problem-based learning strategy who outperformed those taught using the conventional teaching method. It was recommended that both problem-based learning and concept mapping teaching strategies be adopted for effective teaching of chemistry concepts.

Introduction

Science and technology education has gained much attention in today's world because the development of a nation is dependent on science and technological development. Chemistry is a basic ingredient of technology. The application of chemistry in various fields of life cannot be quantified. Research in chemistry and chemical processes has led to improvement of life in the area of medicine, aviation, automobile, infrastructure and others. Chemistry plays a vital role in the provision of man's basic necessities for improved standard of living. The importance of chemistry can never be overemphasised. A student aspiring to study science related courses is expected to pass chemistry at a credit level to be able to gain admission to the university or other tertiary institutions.

Therefore, chemistry teachers are expected to be well-vested in the ideas, processes, techniques and methods of teaching chemistry concepts to enable students understand the subject well so as to apply the knowledge and live meaningful lives.

There is need for teachers to adopt methods of teaching science that are more learner-centred against the teacher-dominated learning/teaching environment.

Students are to be engaged in the learning process with activity-based approaches to enable them have meaningful learning of chemistry concepts and to avoid

stunted knowledge/growth and improve the quality of science teaching and learning.

Science educators and researchers have identified that the use of inappropriate approaches for teaching chemistry is one of the problems militating against the implementation of science curriculum. (Ifeakor, 2006; Jack, 2013). Many emphases have been placed on this by curriculum planners and stakeholders in the educational sector; but, in spite of all these, Nigerian teachers still stick to expository (lecture) or chalk and talk method of teaching rather than activity-based interactive approaches (Ifeakor, 2006).

Available literatures also indicate that poor academic achievement of chemistry students is partly attributed to teachers' teaching approaches, which are mainly teacher-centred, resulting in inadequate opportunity for learners to think and co-construct knowledge. Chemistry is often taught in Nigeria by teachers giving layout procedures or steps to follow toward solving a problem or to perform certain tasks. And when students memorise these procedures and steps and succeed in performing required tasks or operations, teachers believe that the students have understood the concept, therefore, their knowledge of chemistry is full of incoherence thereby causing poor performance in examinations. There is, therefore, the need for chemistry teachers to, through frantic efforts, devise learning styles and approaches that will be activity-packed to promote meaningful learning of chemistry concepts.

Teachers must make renewed effort to ensure their classrooms are purposeful, exciting and interesting. Such interactive and activity-based teaching strategy include problem based learning and concept mapping teaching strategies.

Problem-based learning and concept mapping strategies are learner-centred approaches and involve learning processes where the learners work out products in form of new knowledge by searching for solutions in collaboration with classmates, finding connection between known and new concepts, making decisions on their own. Their teacher only acts as a facilitator to provide guidance and support as well as to direct the necessary process while the students express high level of creativity as they come up with different ideas. In this teaching strategy the basis for understanding and learning new concepts is by connecting the new concepts to the prior knowledge held by the student as opposed to the conventional teacher-dominated method where the teacher struggles to transfer his own knowledge to the students. This conventional approach to learning has led to the low academic achievement of students as it has failed to make students think deeply, liase with classmates as teammates to share ideas and solve problems on their own.

Studies have shown that problem-based learning and concept mapping strategies are both powerful in helping students have meaningful learning and improved academic achievement in chemistry (Oto, 2013; Jack, 2013 & Charif, 2010). Available evidence from studies carried out in Nigeria showed that little research effort has been directed to problem-based learning and concept mapping in the teaching of chemistry in Calabar Education Zone of Cross River State. It is based on this background that this study seeks to find out if, by the use of problem-based learning and concept mapping teaching strategies, students would have meaningful learning of chemistry concepts.

Statement of the problem

The persistent poor performance of students in chemistry has been a great concern to many stakeholders in education. Many researchers have also observed, sadly, that students' achievement in chemistry falls below expectation. Most science classrooms are characterised by teacher-dominated approaches that give rise to inadequate opportunity for students to think, reason things out and solve problems.

Many students see chemistry as a difficult and dry subject thereby showing little interest in the subject. This is capable of hindering them from living up to their dreams and aspirations in life. For instance, students who wish to study professional courses such as Engineering, Medicine, Pharmacy and Nursing

cannot make it without a sound knowledge of chemistry.

Based on this premise, the study seeks to investigate if the use of concepts mapping and problem-based learning strategies in teaching chemistry will enhance students' understanding of chemistry concepts and improve academic achievement.

Purpose of the study

The purpose of this study is to find out if students taught chemistry using problem-based learning and those taught using concept mapping learning strategies will have meaningful learning of chemistry concepts and increased academic achievement in chemistry than those taught using the conventional method. Specifically, the study seeks to find out if there is:

1. Effect of treatment on students' academic achievement in chemistry

Research questions

As a guide to the study, a research question was formulated; this was later converted into a research hypothesis:

1. What is the effect of treatment on students' academic achievement in chemistry?

Statement of hypothesis

The hypothesis formulated for the study is:

1. There is no significant effect of treatment on students' academic achievement in chemistry.

Literature review

Problem-based learning is a learner-centred pedagogy in which learning occurs through problem-solving experiences. Its major aim is to help learners develop problem-solving skills, knowledge that is flexible, skills in collaboration and also the ability to direct their own learning (Wikipedia, 2014). Teachers normally present open-ended "ill-structured problems that have several solutions and the learners are to explore various resources, engage in group discussion as a team and experience problem solving encountered by experts in the field, and their communication is enhanced as they work as a team. (White, 2001). Stanford University Newsletter on teaching (2001) emphasised that "the teacher who serves as the facilitator must be sure that the students' are actively involved in the process of problem-solving. This should make them familiar with the resources required to solve problems, identify difficult areas or misconceptions. And, upon completion of the research or inquiry phase of problem-solving, groups may be required to write reports to be presented to the rest of class".

Concept mapping is a pedagogical/meta-cognitive tool designed to help students learn how to learn, and a concept is a perceived regularity in events or objects or record of events designated by a label which can be a word, a phrase or a symbol, usually circled or boxed and the linking words (usually a word or a phrase) are written on the line linking the concept in the two circles or boxes in a hierarchy making a simple meaningful sentence map (Novak, 1997). See appendix for an example. Concept mapping and problem-based learning strategies have their origin in the constructivism which holds that prior knowledge is used as the basis for understanding and learning new concepts; and it is focused on the premise that concept exists in relationship with others to make meaning rather than in isolation. This, therefore, helps to improve inadequate thinking.

The use of problem-based learning concept mapping teaching strategies has attracted the interest of some researchers. Jack (2013) carried out a study to compare concept mapping and guided inquiry and to find out if they are effective for the teaching and learning of chemistry. The sample was 251 students who were randomly assigned to two groups by balloting. Her analysis of data showed that concept mapping was more effective and superior to the guided inquiry method which was also superior to the expository method of teaching in improving students' achievement in chemistry. Barchok (2014) also studied how collaborative concept mapping (CCM) affects students' achievement in chemistry as well as

how it affects motivation and attitude of students towards learning of chemistry using Mole Concept Achievement Test (MCAT) as the study instrument to measure students' achievement in chemistry.

The findings showed that collaborative concept mapping did affect the achievement of students of low, average and even higher academic abilities. Similarly, Egbo (2014) investigated the effect of concept mapping method of teaching and expository method on the academic achievement of students in chemistry and found that students taught using concept mapping method achieved higher than those taught using expository method. Rahman (2014) studied the effect of concept mapping strategy on students' achievement in science at secondary level and found that the use of concept mapping strategy was more effective than the lecture cum discussion methods in improving students' academic achievement in science. The study carried out by Agboda and Oloyede (2013) to compare the effectiveness of concept mapping and peer tutoring instructional strategies in improving students' performance in chemistry in Ife Central Local Government Area found out that students taught using concept mapping performed better than those taught using peer-tutoring strategy.

Fata de Mogari and Arigbabu (2013) worked on how problem-based learning affects learning of further mathematics among senior secondary school students in Nigeria and found that students taught using problems based learning learnt further mathematics deeply as they scored higher in the post-test than those taught using the traditional method. The study carried out by Charrif (2010) to find out if problem-based learning has any effect on the performance of students and their attitude towards chemistry among Lebanese seventh grade students from a private school. The result obtained from the analysis of data revealed that problem-based learning approach improves students achievement and attitude towards chemistry. Gunter & Alpat (2017) investigated the effects of problem-based learning on students' academic achievement in Electrochemistry. The result of their data analysis showed that students taught using PBL had a better understanding of the subject than students taught using the expository method of teaching.

Similarly, Abanikannda (2016), in his study to find the influence of PBL on chemistry education on the academic achievement of students in Osun State and found that PBL approach was more effective in terms of students' achievement in chemistry and he concluded that when teachers used PBL in the teaching of chemistry they help their students to acquire skills they need in their daily lives such as cooperation, analysis, communication, synthesis and problem-solving skills and that educators should consider the PBL as a teaching strategy to adopt for effective teaching of chemistry.

Methodology

The research design adopted for this study is a pre-test, post-test, control group, quasi-experimental factorial design with treatment variables as independent variable.

The population consisted of all senior secondary schools II (SS 2) chemistry students in Calabar Education Zone. The sample for the study comprised of 124 SS 2 chemistry students selected from six co-educational schools which were selected by simple random sampling technique. Two schools each were randomly assigned to concept mapping, problem-based learning and convention. The experimental group has 82 subjects out of which 42 were taught using concept mapping while 40 were taught using problem-based learning. The control group has 42 subjects and were taught using the conventional method.

The instrument used for data collection include researcher-made chemistry achievement test (CAT). The lesson notes and concept maps were based on selected chemistry topics from the SS2 syllabus for first term in the 2018/2019 academic session. The concept maps and lesson notes were based on the following sub topics in thermochemistry: energy and form of energy, heat content and heat of reaction, exothermic and endothermic reaction. The CAT contains thirty objective test items which focused on all areas taught using the three teaching methods under

consideration. The CAT was designed to measure students' achievement after treatment and the test items were distributed among the six intellectual levels of Bloom's taxonomy in the cognitive domain. The instrument was subjected to face and content validity. To ascertain the reliability of the study instrument, a pilot study was carried out. The reliability coefficient obtained using Kuder Richardson formula (KR-20) was 0.76. The correlation analysis of the scores gave reliability estimate of 0.92. Chemistry teachers from the six schools used for the study were the research assistants who were trained on the use of the teaching methods. The contents, objectives, activities of the students and the research condition were discussed during training. Common instructions were given to the teachers and they took turns to do trial teaching using the prepared lesson notes while the researcher watched and gave necessary correction. The teachers then were given the instructional packages which contained three weeks' lesson plans and lesson notes with all the necessary instructional materials.

Before the commencement of the teaching, a pre-test was administered to students of the two groups to determine their entry behaviour. The pre-test was analysed using analysis of variance and the result obtained showed that there was a statistical significant difference between the experimental and control groups in their pretest scores. This implies that the two groups were not equivalent before the administration of treatment. The experimental group was taught using problem-based learning (PBL) where the teacher gave a mini lecture on the topic to be learnt and then presented the students with real life scenario/problems to be solved, to serve as a stimulus and framework for learning. The students engaged in mental processes of finding solutions, consulted their textbooks, associated ideas and came up with solutions in their small groups. They then presented their solutions and resolutions while the teacher facilitated and directed the process. The students in the experimental groups taught using concept mapping, where the teacher introduced the topic with a mini lecture, noted the key words or phrases including the objects and events in the topic. Students then drew concept maps where they ranked the list of concepts from the most abstract and inclusive to the most concrete and specific concepts. The students in their groups arranged the concepts and linked related concepts with lines and labels while the teacher served as the facilitator. The students in the control group were taught using the conventional method as the teacher gave detailed explanations on the topic/concept to be learnt. The students listened, paid attention and asked questions where they needed clarification from the teacher.

The teaching period lasted for three weeks and it took place simultaneously in all the schools used for the study. The classes were held three times a week and each lesson lasted for 40 minutes. At the end of the teaching period, a post-test was administered to test the effectiveness of the instructional method/strategies. Mean and standard deviation were used to answer the research question while the null hypothesis was answered using analysis of covariance (ANCOVA)

Results

Presentation in this section was based on the research hypothesis.

Hypothesis one:

There is no significant effect of treatment on students' academic achievement. To test this hypothesis, analysis of covariance was applied to the data. The result is presented in table 1. The result shows that there is a significant effect of treatment ($F_{2, 123} = 332.806$, $P<.05$) on achievement. This result indicates that experimental and control groups differ significantly from each other in academic achievement. On the basis of this result, hypothesis 1 is rejected. To show the direction of difference Scheff post hoc test was applied to the data (see table 2). The result indicates that there exists a significant difference between the experimental groups 1 and 2 in their post test scores to the advantage of the experimental group 2 and that experiment

groups 1 and 2 performed significantly better than the control group in the post test.

Multiple classification analysis was also applied to the data (see table 3). The result indicates that the adjusted mean scores for the experimental groups 1 and 2 and the control groups are 27.14, 29.04 and 23.50 respectively,

Table 1
Summary of analysis of covariance on post test scores according to treatment

Source of variance	Sum of squares	df	Mean Square	f-ratio	p-level
Intercept	5656.380	1	5656.380	6175.810	.000
Pretest	57.131	1	57.131	62.378	.000
Treatment effect	609.629	2	304.815	332.806	.000

Model goodness of fit R = .891, R squared = 793

Table 2
Post-hoc comparison of treatment groups for the post –test scores

Groups	N	Man	Mean df	p-level
Exp. Gp. 1	40	27.15	1.897	.018
Exp. Gp. 2	42	29.04		
Exp. Gp. 1	40	27.15	3.65	.000
Control	42	23.50		
Exp. Gp. 2	42	29.04	5.54	.000
Control	42	23.50		

Table 3
Summary of MCA on post-test scores according to treatment

Groups	N	Unadjusted mean	Adjusted mean	Eta	Beta
Exp. Gp. 1	40	27.15	27.14	.635	.889
Exp. Gp. 2	42	29.04	29.04		
Control	42	23.50	23.50		

Model goodness of fit R = .891, R squared = 793

suggesting that the experimental group performed significantly better than the control group. The result also shows that a beta value of .889 for main treatment effect was obtained, suggesting that treatment accounted for only 88.9 percent of variance of scores on post-test measure.

Discussion of findings

The findings of this study showed that students in experimental group 2 who were taught chemistry using concept mapping teaching strategy performed significantly better than their counterparts in experimental group 1 taught using problem-based learning strategy and those in the control group taught using the conventional method. The finding of this study is as a result of the fact that concept mapping is a very purposeful and effective instructional strategy for meaningful learning of chemistry concepts as it stimulates learning in a meaningful way, promoting in-depth learning of chemistry concepts. The students taught using problem-based strategy were able to understand and the learning processes of developing interrelationship creating meaningful schemas and constructing their own knowledge bases led to greater academic achievement. These strategies are constructivist based and student-centred. They involve exploration, engagement, experimentation and investigation among students in their different groups.

This finding agrees with Jack (2013), Barchok, (2014) and Egbo (2014) who found from their studies that concept mapping teaching strategy is effective in the improvement of students' academic achievements as students taught using concept mapping performed better than those taught using conventional method.

This finding also corroborated Rahman (2014) whose study revealed that concept mapping strategy is more effective than the

lecture cum discussion method in improving students' academic achievement in science. The result of this study is consistent with Agbola and Oloyede (2013) who compared the effectiveness of concept mapping and peer tutoring instructional strategies in improving students' performance in chemistry and found that concept mapping is superior to peer-tutoring instructional strategy on their effects on students' achievement.

The finding of this study equally synchronizes Abanikannda (2016) Gunter & Alpat (2017), Charif (2010) who found that PBL is effective in improvement of students' academic achievement in chemistry. The result also draws support from Fatade Ogan & Arigbabu (2013) whose study showed that students taught using PBL performed better than their counterparts taught using the traditional method of teaching in further mathematics.

Conclusion and Recommendations

Based on the finding of this study, the following conclusions were reached.

Problem-based learning and concept mapping lead to insightful learning of chemistry concepts leading to higher academic achievement and should be applied in chemistry teaching in secondary schools. The conventional method should be a complementary method to other activity-based methods as it is not an effective method of teaching alone.

The following recommendations are also put forward:

1. Examination bodies and curriculum designers should prescribe problem-based learning and concept mapping in their syllabus for the teaching and learning of chemistry.
2. The Ministry of Education and school administrators should organise seminars, workshops and retraining programmes to educate chemistry teachers on the use of problem-based learning strategies for effective teaching and learning of chemistry.

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