Effect of Using Multiple Assessment Techniques on Chemistry Students' Performance in Problem Solving

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Abstract

Studies have shown that most Nigerian secondary school chemistry students have difficulty solving problems involving mole and stoichiometric calculations. The study was carried out to find out the effect of using multiple assessment techniques on secondary school chemistry students' performance in problem solving. The pretest-posttest-control group design was employed. Two instruments were developed, validated and used. They were: the chemistry achievement test (CAT, r = 0.80) and the mole and stoichiometry problem solving test (MASPST, r = 0.87). Eighty eight male and female students were randomly sampled from four secondary schools in Mangu LGA of Plateau state and randomly assigned into control and experimental groups. They were pre-tested using the MASPST and instructed for four weeks, covering the mole concept and stoichiometry (including volumetric analysis). Students in the experimental group were treated with a set of classwork, take home assignment, group assignment and written test every week but those in the control were only given an end of month test. At the end of the four weeks, both groups were post-tested using the MASPST and the scores analyzed using t-test ($\alpha = 0.05$). The results of the MASPST show a significant difference between the mean scores of students in the control and those in the experimental group (in favor of the experimental group). The result also show a significant difference in the mean scores of male and female students taught in the experimental group. The study concluded that the use of multiple assessment techniques improves chemistry students' problem solving ability. It therefore recommended that chemistry teachers employ varieties of assessment techniques as part of instructional strategies to teach students problem solving in chemistry.

Introduction

Education has been described as the key to development in any nation - *the back bone of* any progressing nation and teachers are very instrumental in the educational development (Rakesh and Kiran, 2016). Science and technology are among the focus of any nation's educational endeavors. Development in technology goes hand in hand with advancement in science such that any nation that lags behind in science will lag behind in technological development. It is the level of technological development of any nation that is used to judge the nation as developed, developing or underdeveloped. Abdullahi as cited in Gongden (1998) opined that the gap between the rich and poor nations or the strong and weak nations is largely a matter of their level of technological development. Science and technology have always been recognized as the basic tool of industrialization and national development and could bring economic and social happiness by providing employment and improving the welfare of the citizenry The need for a global awareness on the need to improve the quality of science and technology at all levels of education therefore becomes important.

Of the science subjects, chemistry stands out as a backbone such that science and technology which are now hallmark for sustainable development in any national economy cannot strive ahead without chemistry (Festus & Ekpete, 2012). The developed countries forged ahead by recognizing the relevance of chemistry in their national economy. Research evidences have proved that chemistry's contribution to quality of life and nation building are worthwhile

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in all aspects. It was based on this that the Federal Government through her national policy on education made chemistry a compulsory science subject at the secondary school level (Federal Ministry of Education, 2008). There have been researchers such as Eke (2008), accepting that any nation aspiring to be scientifically and technologically developed must have adequate level of chemistry education. These lead chemists in 2008 to declare "what on earth is not chemistry" (Festus and Ekpete, 2012).

As important as chemistry is in the life of individuals and nations, literature is full of reports of students' poor performance in chemistry examinations especially in national and international examinations such as the West African Senior School Certificate Examination (WASSCE) and the National examination Council (NECO). Ezeudu, (2000), Taber & Coll (2002), Ozkaya (2002), Sirhan (2007), Festus and Ekpete (2012) and Gongden (2015) all reported the dismal performance of students in chemistry examinations. Analysis of NECO results showed that the percentage credit pass of students in chemistry during the November/December General Certificate of Education examination for 2011, 2012 and 2013 were 5.32%, 30.17% and 66.41% respectively (Mosadomi, 2013). The analysis of the WASSCE results from 2001 to 2015 shows that the highest percentage (credit) pass recorded in chemistry was 50.70% in 2010. Some of the areas found to be difficult include rate of reactions, mole concept, electrolysis, stoichiometric calculations and chemical equilibrium. Johnson Publisher (2015) notes that from 2004 to 2014, questions requiring problem solving in WASSCE accounts for 82% of the theory part while such questions account for 79% of the practical part. This indicate that if students are made to improve in their problem solving ability, the tendency that they may do better in the WASSCE and NECO will be high. Various reasons have been ascribed to the difficulty to include lack of conceptual understanding (Ezeudu, 2000; Ozkaya, 2002), students' inability to solve chemical problems (Crippen, Brooks, & Courtright, 2000; Gabel, 2003a), defective teaching methods (Gable, 2003a; Gongden, 2015), lack of facilities, misconceptions, teachers' qualifications (Njoku, 2003; Udofia, 2006), students' and teachers' attitudes (Festus & Ekpete, 2012), etc.

Various studies on gender and students' performance in chemical problem solving tasks have over the years, been committed to the effects of gender on students' performance in chemistry and other science subjects have not even yielded consistent and definitive results (Gongden, 2015). Casey (2001), Dhindsa &Emran (2011) observed that most studies on gender difference report male dominance. Kumar and Helgeson (2000) studied the effects of gender on computer-based chemistry problem solving using Hyperequation on the Macintosh computer platform. Results show no significant difference between male and female students solving stoichiometric chemistry problems using the Hyperequation software on Macintosh Computer. Other research works that showed no significant difference between male and female students include those of Inyang and Jegede (1991), Jimoh (2004),Erinosho in Adesoji & Babatunde (2008),and Udousoro (2011). This is in contrast with the earlier finding of Ahiakwo (1988) and Shuaibu and Mari (1997) who had reported that female students performed better than male students in problem solving tasks. Armagan, Sagir and Celik (2009), also reported a situation in favor of females when they investigated the effect of problem solving skills on achievement of male and female chemistry

A lot of attention has been focused on the teacher with a view to ameliorating the problem of poor performance in chemistry. This is in line with the understanding that no education system can be better than the quality of its teachers and no skill can be developed without the help of a teacher. Ibukun (2009) buttressed this fact when he stated that no system of education can rise above the qualities of its teachers. Teachers play a great role in how students understand and learn the concepts taught in class. Studies show that teachers reflect their already-existing conceptual constructs and their problem-solving processes on students (Kolomuç & Tekin, 2011). They do so through the teaching strategies employed. Gabel (2003a) noted that teachers do not present the concepts in a variety of contexts for students to understand but in verbal and formal ways. This view and other reports suggested the need to find out which instructional

strategies can best influence students' problem solving performance in chemistry. Metacognitive instructional strategies were developed and used but the performance of students in chemistry and particularly, problem solving has not improved appreciably.

As a result of this unfortunate trend, Davies (2006) opined that there is the need for a teacher to ask themselves questions such as: is the teaching strategy effective or not? Has the student learnt meaningfully? Which concepts have been clearly understood and which one is difficult? Is the entire lesson to be repeated? These and other questions help the teacher to assess the teaching – learning process thereby enabling the teacher to know whether or not the objectives have been achieved. This brings to mind the importance of assessment during instruction. Teaching – learning process cannot be said to be effective unless there is effective assessment. Assessment here refers to the determination of the extent of students' progress or lack of it in school subjects including attitudes and values (National Teachers' Institute, 2000). It could be systematic (progressive, continuous) or one shot (such as in terminal examination). Assessment is formative when it aims at monitoring the progress of a learner during instruction in order to provide continuous feedback to both teacher and student (Joshi, 2005). It is summative when it aims at determining the achievement of a learner at the end of a course for the sake of assigning grades or certificates. In a broad sense, assessment is any methods used to better understand the current knowledge that a student possesses (Collins & O'Brien, 2003). According to Crooks (2001), assessment is any process that provides information about the thinking, achievement or progress of students. Because assessment is important in teaching and learning, instructors assess their students' learning regularly. Some of the methods or techniques which instructors use to measure their students' learning are oral-questioning, project work, classroom work, group assignment; take home assignment, written tests, book reports and question-and-answer activities. These assessment techniques are also learning techniques in the sense that their practice improves teachers' quality of instruction since students are regularly fed with their performances.

Quite a number of researches have been carried out on the use of assessments to improve learning. Coopper, Robinson and Patall (2006) and Trautwein (2007) reported that homework influences students' achievement positively and help students make gains in their achievement. Homework is proved to be effective in mathematics. Coopper, Robinson and Patall (2006) and Trautwein (2007) found out that homework influences students' achievement positively and helpsthem make gains in their achievement. Chollom (2013) investigated the effect of wait- time during oral questioning in primary five science class to promote thinking in pupils. Similarly, Baniabdelrahman (2010) found that different kinds of assessments can be used to provide reliable information about students' learning progress. Stiggins (2001) also suggests that teachers should always spend a great deal of time using one type of assessment or another. A look at the studies carried out on the assessment of students reveals that there is much more to be done in this direction – hence this study.

Statement of the Problem

Assessment is an integral part of teaching and learning process and usually involves different types of assessment techniques (Agbo, 2009; Beskeni, 2009; Santrock, 2009). Such assessments are used to collect and describe data for the sake of taking decisions about the process in general and students' achievement generally. It is through assessment that we get to know whether or not, desired changes have taken place in learners or not. Various studies have been carried out on the role of assessment in improving teaching and learning. These include the works of Awotunde and Ugodulunwa (2001), Patall (2006), Yell (2008) and Agbo (2009). Very few (if at all) concern the teaching and learning of chemistry. Specifically, studies on the effect of multiple assessments during the teaching of mole and stoichiometry have not been documented. Does the use of multiple assessment techniques helps students improve their problem solving ability in chemistry? How do male and female chemistry students vary in their problem solving ability when exposed to multiple assessment techniques during instruction?

Objective of the Study

The study was carried out in order to find out if the use of multiple assessment techniques (class work, take home assignment, group assignment, written tests) will improve students' performance in problem solving involving mole and stoichiometric calculations. Specifically, the study shall:

i. Find out if students exposed to multiple assessments techniques do better than those not exposed to in chemistry problem solving tasks
ii. Find out if male students differ from the female students in problem solving ability when both groups are exposed to multiple assessments.

Research Questions

i. To what extent do the scores of chemistry students exposed to multiple assessment techniques differ from those not exposed in problem solving?
ii. To what extent do students' performances in chemistry problem solving differ due to gender after exposure to multiple assessment techniques?

Research Hypotheses:

i. There is no significant difference between the mean scores of the chemistry students exposed to multiple assessments techniques and those not exposed to.
ii. There is no significant difference between the mean scores of the male and female chemistry students exposed to multiple assessments techniques.

Materials and Methods

The objective of the study was to find out the effect of multiple assessment techniques on students' performance in problem solving tasks in chemistry. As such, the design used was pretest-post-test control group (experimental) design. The purpose of the experiment was to show that any difference obtained between the initial scores and the final scores in the groups were as a result of the different treatment received by each group. The main strength of this design is that the initial random assignment of subjects to the groups and the administration of a pretest to all the groups help to control all threats to internal validity.

The population of the study was all the senior secondary two chemistry students in Mangu LGA of Plateau state. Members of the population share certain common characteristics which include: the same curriculum/syllabus, preparation for the same external examinations (WASSCE and NECO), their being from different socio-economic, cultural backgrounds and religious backgrounds and a common way of evaluation. Four schools were sampled (the study being an experimental study) and a total student sample of eighty eight randomly selected from the four schools.

Two instruments were used: the chemistry achievement test (CAT) and the mole and stoichiometry problem solving test, (MASPST). The CAT was a 40-item multiple choice test with four alternative responses A-D among which only one was correct. The questions were drawn from past Senior School Certificate Examination and from topics such as particulate nature of matter, kinetic theory of gases, laws of chemical combinations and other areas in chemistry that provides the necessary background knowledge for solving the problems in the MASPST. Even though the items were adapted from WASSCE which is a standard examination, the researcher still validated them, first by establishing its face and construct validity. A 50-item test was developed and given to some secondary chemistry teachers to go through. They helped to ensure that the instrument was not only clear, suitable to students' level, appealing, but consisted of items drawn from the secondary school chemistry curriculum and designed to measure the students' problem solving ability which it is supposed to measure. It was then given to chemistry education experts for critique. The critiques of the experts were taken into consideration and the 40 items were recommended. The reliability of the instruments was determined using the Split-Half method. The scores on the odd items were correlated against those of the even items using the Pearson Product-Moment Coefficient (PPMC) of correlation formula. To avoid a deflated figure, the researcher used the Spearman Brown formula to estimate and hence correct the reliability of the CAT. The reliability coefficient was found to be 0.80.

The MASPST consisted of six questions (problems to be solved) drawn from the mole, stoichiometry and volumetric analysis. The validity

was established as in the case of the CAT. In order to determine the reliability of the MASPST, an appropriate method known as the inter-scorer method (Danjuma, 2005) for determining the reliability of an essay test was used. The CPST was administered to respondents and their scripts given to two experts in chemistry education to score independently using the scoring guide. The scores by one of the experts was correlated against those of the other expert using the Pearson Product-Moment Coefficient (PPMC) of correlation formula. The computation gave a correlation coefficient of 0.87.

In order to get the student sample that will be equivalent (equality of groups), two instruments, the chemistry achievement test (CAT) was administered to the senior secondary two chemistry students in the four schools. Students who scored forty and above in the CAT were considered to have the requisite chemical skills for problem- solving in chemistry and hence qualified as sample for the study. The researcher also considered it a score that is not too low but believed that if a student can get 40 out of 100 marks, the tendency that they can benefit from learning (treatment) is fairly high. A sample of eighty eight students (made up of forty four males and forty four females) was randomly drawn from the population of the chemistry students from the four schools (who scored forty and above). The eighty eight students were randomly assigned into two groups and each group pre-tested with mole and stoichiometry problem solving test, (MASPST). The randomization and pre-test also helped establish the equality of the groups.

This was followed by four weeks of teaching the mole concept and stoichiometry in the control and experimental groups using the conventional method. The teaching was carried out by research assistants who are chemistry education graduate teachers. The experimental class was given a class work, take home assignment, group assignment and test every week while the instruction lasted, while the control was given only an end of month test. At the end of the four weeks, both groups were post-tested and the scores analysed.

Results

The data obtained from the MACPST were analyzed using t-test and compared at 0.05 level of significance. The results were presented appropriately and used to answer the research questions and test the null hypotheses. The result of the post-test was as follows:

Research Question One: To what extent do the scores of chemistry students exposed to multiple assessment techniques differ from those not exposed in problem solving?

Table 2: Group statistics (t-test) for expt. and control group (post test performance)

Group	N	Mean	Std Dev	Std Error Mean
Expt	44	16.91	3.064	0.462
Control	44	14.86	2.483	0.374

Results presented in Table 2 shows that the mean score of students in the control group was 14.86 while that of students in the experimental group was 16.91. The mean scores were not the same. There was a difference (2.05) in the mean score of chemistry students treated with multiple continuous assessments techniques and those in the control class.

Table 3: Independent sample test for expt and control (equality of means)

	Mean diff	t	df	SE diff	P-sig 2-tailed
Equal var. assumed	2.05	3.44	86	0.59456	0.001
Equal var. not assumed	2.05	3.44	82.47	0.59456	0.001

Hypothesis One: There is no significant difference between the mean scores of the chemistry students exposed to multiple assessments techniques and those not exposed to.

In table three, comparison of the mean score of the experimental and the control yielded a p-sig value of $0.001 < 0.05$. This means that there is a significant difference in the mean scores of the experimental group and the control group (in favor of the experimental group). The null hypothesis

was rejected in favor of the alternate. Therefore there is a statistically significant difference between the mean scores of the chemistry students treated with multiple continuous assessments techniques and those in the control class.

Research Question Two: To what extent do students' performances in chemistry problem solving differ due to gender after exposure to multiple assessment techniques?

Table 4: Group statistics (t-test) for male and female (Expt. group)

Group	N	Mean	Std Dev	Std Error Mean
Male	22	18.182	2.9218	0.6229
Female	22	15.318	2.6074	0.5559

Table four gives the results of the male and female students that were treated in the experimental group with the assessment techniques. The mean scores show a difference of 2.834 in favor of the male students. There was a difference in the mean scores of male and female chemistry students that were treated with multiple continuous assessments techniques.

Table 5: Independent sample test for male and female (Expt group)

	Mean diff	t	df	SE diff	P-sig 2-tailed
Equal var. assumed	2.864	3.43	42	0.835	0.001
Equal var. not assumed	2.864	3.43	41.47	0.835	0.001

Research hypothesis Two: There is no significant difference between the mean scores of the male and female chemistry students exposed to multiple assessments techniques.

Analysis of the mean scores of the male and female students show that at $\alpha = 0.05$, p-sig = 0.001. $P < 0.05$. Therefore the null hypothesis is rejected in favor of the alternate. Therefore there is a statistically significant difference between the mean scores of the male and female chemistry students treated with multiple continuous assessments techniques.

Discussions

The results of the study show that there was a significant difference between the mean scores of the students treated with multiple assessment techniques and those in the control. The students in the experimental group performed better in chemistry problem solving tasks than those in the control. This result is in line with results of Stiggins (2001), Coopper, Robinson & Patall (2006), Trautwein (2007) and Baniabdelrahman (2010) – who all established the usefulness of multiple assessments and suggested that different kinds of assessment be used to provide reliable information about students' learning progress. Assessment techniques which particularly engage learners in self-assessment have positive effect on students' performance. The reason for the significant difference may be ascribed to the constant exposure of the students to problem solving activities. Students in the experimental class were given one form of assessment or the other almost every day. Participation in the assessment task keeps them abreast with learned tasks and the teachers' response through scoring their works provided them with knowledge of their progress. They are able to evaluate themselves, make corrections and seek to understand better. The results however disagreed with Struyven, Dochy, Janssens, Schelfhout and Gielen (2006) who posited that multiple assessments do not produce overall effects on students' performance/learning because not all assessments produce desired and comparable results.

Another finding is that there was a significant difference between the mean scores of male and female chemistry students treated with multiple continuous assessments techniques. The male students performed better than the females in chemistry problem-solving tasks than the females, even though they were treated the same way. This result established a better performance by the male students over females in chemical problem solving. The result is in line with those of Adigwe (1992), Adesoji & Babatunde (2008) and Dhindsa & Emran (2011)who found separately that male students excelled over female students in problem solving processes.

The results did not agree with those of Gongden ((2015) and Gongden and Delmang (2016) who found that no significant difference existed between the posttest means scores of male and female students taught using concept mapping strategy. Similarly, Kumar and Helgeson (2000), Ogundere and Aderogba (2009), Viko (2010) found that both male and female students benefitted almost equally from self assessment in chemistry. Chemistry achievement scores and the mean chemistry self-efficacy scores of male and female students exposed to self assessment skills were not significant. The reasons for male students' edge over the female may be due to the findings that boys have greater science related experiences outside the classroom. They evidence more positive attitude toward science and benefit more from interactions (Walding, 2002) as they sit to do group assignments and others that require interactions.

Conclusion

The study was carried out to find out the effect of using multiple assessment techniques on secondary school chemistry students' performance in problem solving. Based on the analyses, interpretations and discussions of the findings of the study, multiple assessment techniques produced greater effect than once in a month test. The results revealed that problem solving in chemistry can be improved upon if chemistry teachers take time to use multiple assessment techniques on their students during instruction. Both male and female chemistry students benefitted from the multiple assessment techniques. Male students however, benefitted more than female students in chemistry problem solving test when multiple assessment technique was used. The study therefore established the efficacy of multiple assessment techniques in chemistry problem solving tasks involving mole and stoichiometry.

Recommendations

The study recommended that chemistry teachers employ varieties of assessment techniques as part of instructional strategies to teach students problem solving in chemistry. There should be a deliberate effort on the part of curriculum developers and planners to include and multiple assessment techniques to chemistry teachers. Chemistry teachers' training programs should include a deliberate preparation of teachers for the acquisition of skills needed for assessing students. Education authorities and professional bodies should organise seminars, workshops, refresher courses and conferences on the use of assessment to improve students' performance in chemistry and other science subjects.

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