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INCORPORATING ERROR ANALYSIS APPROACH INTO THE TEACHING OF PRACTICAL CHEMISTRY IN SENIOR SECONDARY SCHOOLS IN MAKURDI NIGERIA: ANY EFFECT ON ACHIEVEMENT?

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ABSTRACT

This study focused on the effect of incorporating error analysis approach in teaching practical chemistry on students' achievement in senior secondary (SS) school chemistry. The study was carried out in Makurdi Metropolis using SS2 chemistry students. Both purposive and simple random sampling techniques were employed to select the sample (N = 132) from the 28 government approved schools. Four intact classes were used and the members of these intact classes constituted the sample. Practical Chemistry Achievement Test (PCAT) was used for data collection. Using Spearman Rank Order, the reliability coefficient of PCAT was found to be 0.71. The data collected were analyzed using mean and standard deviation to answer the research questions while Analysis of Covariance (ANCOVA) was used to test the hypotheses at the 0.05 level of significance. The findings reveal that the experimental group showed significant mean gain in achievement towards chemistry learning ($P = 0.0001 < 0.05$). On the basis of gender there was no significant difference in the achievement of both boys and girls in the experimental group ($P = 0.775 > 0.05$). Some of the recommendations among others are that chemistry teachers should be trained in the use incorporating error analysis approach as a teaching strategy and that chemistry teachers should be motivated not to restrict themselves to the subject contents only but teach practical along with identified errors also.

Keywords: Chemistry practical, Error analysis, Qualitative analysis, Quantitative analysis, Teaching practical, Chemistry achievement.

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1. INTRODUCTION

Chemistry is one of the physical sciences taught at the senior secondary school. Education particularly in chemistry is the instrument through which the immense height of technology evident in the developed countries was attained and through which, Nigeria as well as other developing countries could come to grip with the needed technology. Accordingly to Akinsola and Igwe (2002) see chemistry as an important science subject that occupies a prominent place in the school science curriculum; it serves as a prerequisite for the study of medicine, pharmacy, agriculture, engineering, textile and clothing. They also observed that chemistry is pre-occupied with molecular transformation and manipulation of matter. This implies that chemistry is involved in industrial set-up and the improvement of quality of life of the citizenry. It appears that without chemistry there can hardly be science because, the scientific development of any nation is determined by the quality of chemistry education in its schools (Okafor, 2003).

The essence of science education from the simple fact reveals that adequate knowledge of modern science is pre-requisite for advance technological culture. Nworgu quoted by Awa (2003) argued that unless we continue with science and gather correct knowledge whether or not it seems useful at the spot, we will be buried under our problem and find no way out. Chemistry like any other science subjects is an activity (practical) oriented. Practical occupies a very important place in the curriculum, teaching, and mastering of the subject. The good performance of students in practical activities seems to be an indication of good knowledge of the subject due to the value attached to practical work as a result of the nature of the subject. The nature of chemistry as a science subject emphasizes more on practical than theory. It means no meaningful teaching and learning could ever take place without adequate practical. Practical is considered fundamental and bedrock in teaching and learning of chemistry (Awa, 2003). Scientist acquires and sustains knowledge through experimentation (practical). This approach is necessary because according to Federal Republic of Nigeria (Federal Republic of Nigeria (FRN, 2004), the essence of science education which chemistry is one is to teach the child what science is and how a scientist works. The National Policy on Education (Federal Republic of Nigeria (FRN, 2004) emphasizes doing science and not talking science. The implication of practical being the bedrock in teaching and learning of chemistry is that, it has to be child-centered, exploratory and creative in its approach, since it is geared towards laying a solid foundation for realizing the desired manpower for the technological development of both the individual and the society. Chemistry is one of the core subjects in the present system of education. Accordingly, the objectives are: to observe and explore the environment; develop basic scientific process skills which are observing, experimenting, manipulation, classifying, communicating, inferring, hypothesizing, interacting with data and formulating models. It is also to develop functional knowledge of science concepts and principles; explain simple natural phenomena; develop scientific attitudes, including curiosity, critical reflection and objectivity. It equally involves applying the skills and knowledge gained through problem solving; self confidence and self-reliance through problem solving; develop a functional awareness to the orderliness of the beauty of nature (Federal Republic of Nigeria (FRN, 2004). Achievement of these objectives demands carrying out practical.

The fact that many teachers rather talk chemistry and neglect the practical aspect of the subject has contributed to students' failure in the subject. In some schools where there are qualified teachers, their laboratories are poorly equipped and some available equipment are not in good condition. It is a common practice that most teachers do not expose their students to chemistry practical until in their SS3 when it is already late to impact adequate knowledge and skills to the students. Besides, in most schools, the chemistry teachers have neither teaching nor chemistry qualification. One wonders how such teachers teach meaningfully especially the practical aspect of the subject. The fact has remained that Chemistry practical has been unduly neglected in some of our schools. It is obvious that we are now in the era where advancement in science and technology is the yardstick for development. Development truly depends to a large extent on how much the citizens of a nation can produce technologically as well as the quality of those products such as drugs, cosmetics, plastics and others. Therefore, neglecting chemistry practical by teachers would have adverse effect on the development of the nation.

Achievement can be referred to as academic attainment of students. In this work it is regarded as the academic attainment of SS2 students in chemistry. It is usually determined through assessment using assessment techniques such as test and examination. The student achievement (educational outcome) in chemistry over the years is not satisfactory. This unsatisfactory state arises from the fact that the attainment of secondary school students in science especially chemistry has continued to deteriorate over the years (West African Examination Council, 2006; Asim, 2008). The West African Examination Council (WAEC) Chief Examiner's Report shows that less than thirty percent (30%) of the total students who sat for chemistry passed at credit and above in the West African Senior School Certificate Examination (WASSCE). This is further confirmed by evidences from literature review that shows that students do not perform well in sciences including chemistry (Onwuakpa and Akpan, 2001; Chukwuneke and Nwachukwu, 2005).

Meanwhile, a review of students' achievement in Senior Secondary Certificate Examination (SSCE) in Chemistry in Nigeria from 2001 to 2010 seems to confirm the same trend of poor/fluctuating performance. The West African Examination Council (2009) on students' performance in chemistry show that candidates' performance was not generally impressive and that there is no marked improvement over the performance in previous years. This is an indication that students still have problem in understanding chemistry.

It has also been observed that low percentage pass in science subjects at senior secondary school certificate examination was partially due to errors students made in practical (Lawan, 2006). Students often attempt to solve practical problems by trial and error or by involving a solution presented in class or laboratory to a problem that they wrongly assumed to be similar to the one which they are solving. Their inability to tackle quantitative and qualitative problems in chemistry has been attributed to students' negative attitude to chemistry learning and the difficult nature of some concepts in chemistry (Oloyede, 1998).

Sometimes students' achievement differs due to gender. However some previous studies indicate no significant difference between boys and girls (Dimitrov, 2002; Duguryil, 2004). These studies found that the poor achievement of students in sciences is common to both sexes and that when a good method of instruction is used both sexes improve similarly. On the other hand, Soyibo (2001) found that girls perform better than boys on test of errors in biological labeling though the difference was found to be statistically insignificant.

One of the greatest problems in implementing chemistry curriculum has been the use of inappropriate approach for teaching. It is obvious that teachers still use mainly conventional method to deliver skills and knowledge of chemistry to students (Akpoghol, 2006).

Based on the relevance of chemistry, it would be pertinent that students should be helped to acquire appropriate learning strategies that would equip them in learning chemistry principles and knowledge for effective learning outcomes. It is to be put on note that the use of conventional methods in teaching has not really produced the desired result or effectiveness judging by the recurring poor performance of students in SSCE results (Anaekwe, 2006). Many science educators are now beginning to solicit that teachers should try innovating methods that may perhaps bring the desired result. The implication of these as a matter of emphasis, are that there is every need to explore new ways of enhancing effective teaching and learning of STM education, chemistry in particular in secondary schools. Consequently, innovative approach like incorporation of error analysis could be given a trial. Hebden (2005) identified incorporating error analysis as one of the teaching strategies one can adopt while teaching chemistry. A science teacher should try so many approaches with the aim of discovering which one is most efficient in helping the students to have better understanding of the subject matter.

A teaching approach that clearly defines what errors are and what should be done, when tackling a problem encourages good learning habits, pin-point areas of confusion, clarifies thinking and promotes intellectual development is necessary for teaching and learning of any science subject. Bounce (2001), observed that solving chemical problems also require both conscious and systematic application of acquired chemical information. Error analysis is a teaching approach that emphasizes what are errors in a subject and allows related errors to be taught along side with the content (Hebden, 2005). The approach teaches students errors for the purpose of avoiding them in their work. This approach helps to clarify issues, eliminate confusion and make understanding of facts easier. According to Akpoghol (2006), meaningful learning is achieved when effective teaching method is used. The purpose of this study therefore is to determine the effects of incorporating error analysis approach in teaching practical chemistry on students' achievement in senior secondary chemistry. Specifically, the study seeks to pursue the following objectives:

1. Find out the effect of incorporating error analysis approach on students' achievement in chemistry practical when compared with those taught using laboratory method only.
2. Investigate the extent of differential effect of incorporating error analysis on achievement of boys and girls.

1.1. Research Questions

To assist in achieving the objectives of this study, the following research questions are answered:

1. How would the effect of incorporating error analysis approach on students' achievement in chemistry practical differ when compared with those taught using laboratory method?

2. To what extent is the difference between the achievement of boys and girls taught chemistry practical by incorporating error analysis approach?

1.2. Hypotheses

The following null hypotheses were tested at 0. 05 level of significance.

1. There is no significant difference in the mean achievement scores between those taught chemistry practical by incorporating error analysis and those taught using conventional method (laboratory method).
2. There is no significant difference between the mean achievement scores of boys and girls taught practical chemistry using error analysis approach.

2. LITERATURE REVIEW

Udoka (2002) conducted a study in Awka on effect of incorporating error analysis approach in teaching selected topic in chemistry on students' achievement in senior secondary school chemistry. A total number of sixty-two (62) senior secondary school students (SS II) were grouped into Group I (treated with inquiry method) and Group 2 (taught using lecture method). All teaching lasted for six weeks to cover electrolysis and separation techniques. The result revealed that, students' mean Chemistry achievement score was significantly higher for the experimental group taught with incorporating error analysis approach than the control group. The differences in students' mean chemistry achievement scores on the basis of gender across the experimental group were negligible which showed that the treatment was gender friendly.

Evidences from literature show that secondary school students do not perform well in sciences including chemistry in Nigeria (Chukwuneke and Nwachukwu, 2005; Onwuakpa and Akpan, 2001). This was further buttressed by West African Examination Council (2009) and Lawan (2006) with particular reference to chemistry results. The goal in the chemistry laboratory is to obtain reliable results though with the understanding that there are errors inherent in any laboratory technique. Some laboratory errors are more obvious than others. Replication of a particular experiment allows an analysis of the reproducibility (precision) of a measurement, while using different methods to perform the same measurement allows a gauge of the truth of the data (accuracy). According to Zumdahi (2000), there are two types of experimental error: systematic error and random error. Systematic error arises from a flaw in experimental design or equipment and can be detected and corrected. This type of error leads to inaccurate measurements of the true value. On the order hand, random error is always present and cannot be corrected. An example of random error is that which arises from reading a burette, which is somewhat subjective and therefore varies with the person making the reading. This type of error impacts the precision, or reproducibility, of a measurement. The goal in a chemistry experiment is to eliminate systematic error and minimize random error to obtain a high degree of both accuracy and precision. Sources of random error will differ depending on the specific experimental techniques used. Some examples might include reading a burette, the error tolerance for laboratory balances, etc. Sources of random error do not include calculation error (a systematic error that can be corrected). Also a mistake in making solution is a systematic error. Two relevant theories were considered in this study: the theory of operant conditioning and investment theory of creativity. The theory of operant conditioning was propounded by B.F Skinner, a famed psychologist in 1957. The theory holds the idea that human beings respond predictably to stimuli, and those who control those stimuli control the person. There is no free will as commonly conceived; only responses to perceived pleasures and pains. The basic idea therefore is that if you want to treat irrational behaviour you must make certain that the irrational behaviour will disappear, because it eventually conditions the agent to realize that such behaviour leads to pain. The implication of this theory is that human being is a product of interaction with the environment. That is to say human behaviour can change when properly motivated. This has relevance to this study because the research work aimed at using instructional strategy to cause a response in the learner. That is to say, this work is directed towards producing a behaviour or effect in the learners which can motivate learning of chemistry. Another theory relevant to this work is Sternberg and Lubart investment theory of creativity (thinking and doing ability). This theory was propounded by Sternberg and Lubart in 1991. The learners' psychomotor development aspect of this work, the investment theory of creativity (thinking and doing ability) is relevant. The theory assumes that student' doing ability becomes rewarding when they pursue ideas that have growth potential. The theory maintains that thinking and doing ability requires a confluence of six distinct but interrelated resources namely: intellectual ability, thinking style, knowledge, personality, motivation and environment. These are required in an individual for meaningful doing ability to be exhibited. According to the proponents of this theory, three intellectual abilities are important in doing ability. These include synthetic ability which means to see problems in new ways and to escape the bounds of conventional thinking; analytic ability, which means to recognize which ideas are worth pursuing and which are not; and practical contextual to persuade others to accept the value of one's ideas. The confluence of these psychomotor domain levels of intellectual abilities is very important in doing ability and production.

Also, the proponents of this theory considered knowledge as an essential ingredient to practical work. The theory emphasizes that one need to know enough about a field to move it forward. What one knows determines how meaningful one can move beyond the way in which one has seen a problem in the past. The style of one's thinking matters, the issue here is not that one is thinking but how logically, globally, and locally; to be able to distinguish the forest from the trees and thereby recognizing which questions are important and which ones are not.

Besides, personality attributes are essentially important when it comes to doing ability of students. Such attributes as willingness to take sensible risks and composing of one's self is very essential. Furthermore, motivation is another essential factor to be considered. Students according to them rarely do any practical work unless they are properly motivated. A supportive and rewarding environment is needed for students to exhibit the doing potential logically and rationally. The implication of this theory is that the much a student can do psychomotor wise depends on his intellectual ability, how knowledgeable he/ she is in the field, and his/her personality as revealed in his/her attitude also. If a student is given proper motivation and a very supportive environment, his performance at the psychomotor domain is being encouraged which likely promotes right style of thinking in him. This theory is very relevant to this work because it is interested in supplying knowledge to students capable of motivating them to learn chemistry and improve their performance in practical chemistry work. It is also interested in creating students who understand science in a way that will enable them participate intelligently in critical thinking, decision making and problem solving. The students who possess the right attitudes, habits and saleable skills perform well practically. This work tends to help students develop scientific understanding, scientific thinking and manual skills.

3. METHODOLOGY

The design used in the study is a quasi-experimental design and of pretest-posttest non-randomized group type. The reason for adopting this design is because the nature of the problem of this research is to establish cause-effect. Also this design was plausible because subjects were assigned to classes on the basis of their school subject offerings and so intact class was used.

This study was restricted to Makurdi Metropolis of Benue State. There are twenty eight accredited government approved senior secondary schools in the metropolis as of April 2011.

The target population was 1280 SS2 in Makurdi metropolis. Population is a description of all the respondents or events within the research location (Achor and Ejigbo, 2006). The choice of SS2 chemistry students is because the students were assumed to have acquired rudimentary knowledge in chemistry practical. The population of SS2 chemistry students was drawn from the 28 accredited senior secondary schools in Makurdi metropolis. The sample for the study consists of one hundred and thirty two (N = 132) SSII chemistry students'. Both purposive and simple random techniques were used for selecting sample from the target population. Four schools were purposively selected from the twenty eight government approved schools. The criteria for the purposive selection were based on co-education, five years presentation of candidates for West African Examination Senior School Certificate (WASSCE) and National Examination Council for Senior School Certificate Examination (NECO SSCE) and having well equipped laboratories. This excluded single schools, schools that do not have well equipped laboratories as well as those that have not presented candidates in chemistry up to five years. Hat and draw approach was then employed in the simple random selection. Using a simple random sampling technique, two intact classes were selected as experimental group from the four schools and another two intact classes as control group. The members of the four intact classes constituted the sample which represents the entire senior secondary school chemistry students in Makurdi metropolis.

The students used for this study have in addition to selecting chemistry as a school certificate subject, have acquired some practical knowledge. Out of 132 students, 68 were members of two intact classes used as control group, while 64 students were members of the two intact classes used as experimental group. Experimental group consist of 30 boys and 34 girls while the control group had 36 boys and 32 girls.

3.1. Instrument

The instrument used for data collection was Practical Chemistry Achievement Test (PCAT) constructed by the researchers. The practical chemistry achievement test was designed to measure students' achievement in practical chemistry in the area of volumetric analysis and qualitative analysis. The PCAT contains two practical essay questions having sub questions in line with WAEC and NECO standard of setting chemistry practical questions. Question one which is on quantitative analysis contains three sub-questions while question two which is on qualitative analysis contains four sub-questions. Therefore the PCAT contains a total number of seven (7) questions. The PCAT was drawn from concepts taught under the following topics: titration and recording, calculation in acid-base titration, identification of anions and cations. The students of both experimental and control groups were required to carry out the practical, record their results and do some calculations. Observations and inference were recorded as well.

A quantitative analysis part of the PCAT was designed to:

a) Test students' knowledge of practical activities in volumetric analysis

b) Calculation of concentration in moles per dm^3 of a dilute acid of unknown concentration

c) Concentration of hydrogen tetraoxosulphate (vi) acid in $gldm^3$ and equation for the reaction is $2NaOH + H_2S0_4 \rightarrow Na_2SO_4 + 2H_2O$.

Each of the students was provided with titration apparatus in addition to 25O cm^3 of each of the solutions (acid and base). The qualitative part of the PCAT is designed to test students' knowledge of practical activities in qualitative analysis of a sample. Students were required to carry out the test on $CuCO_3$ sample as sample X, record their observations and inferences.

3.2. Instructional Approach

The error analysis approach which involves emphasizing the correct things alongside with the errors for the purpose of identification and avoidance was adopted. This approach was adopted only as instructional procedure by the teacher of the experimental group Emphasis was on the students to avoid committing such errors. In the lesson plans for the experimental group, the errors incorporated in teaching volumetric and qualitative analysis were obtained from literature review of WAEC Chief Examiners' report on errors committed by the students in the past WAEC practical chemistry examinations. In the course of teaching, practical chemistry works were given to students, marked and corrected by their teachers. Then, students were required to identify the errors they committed in their practical work marked for the purpose of avoiding them when carrying out such experiments. While in the lesson plan of the control group, neither were these errors were not incorporated nor were the students required to identify any error in their practical work marked. However normal laboratory approach was used to conduct the practical. The PCAT, the marking scheme and the lesson plans were given to expert lecturers from the department of curriculum and teaching of Benue State University to do face and content validation. They were asked to correct the instruments where necessary. They were also requested to make their recommendations as to whether they were suitable for SS2 students to appropriately interpret and respond to. Similarly, they examined the suitability of the lesson plans in teaching incorporating error analysis approach lesson as well as using normal laboratory method. They also examined the suitability of the marking scheme in relation to the marking of the PCAT. Some corrections were made but the seven questions contained in the PCAT were upheld because they agreed that the questions covered the topics to be treated adequately.

The reliability of the validated instruments was ensured through the pilot study. Spearman Rank Order was used for PCAT and reliability co-efficient of 0.71 was obtained. This shows that the instrument is reliable. According to Julie (2004), for instrument to be reliable, the reliability co-efficient should be in general 0.7 and above. The authorities of each of the four schools were contacted to allow the research to be carried out in their schools with their SS2 chemistry students. Four chemistry teachers who are holders of B.Sc. (Ed) were used as research assistants. Two were trained by the researcher for one week to assist in teaching the experimental groups. This was with the aid of a training guide prepared for the purpose.

The teaching approach was explicitly described and demonstrated using a topic taken from SS2 chemistry syllabus. In order to be sure that the research assistants trained mastered the use of incorporating error analysis approach to teach the practical chemistry topics, the researchers evaluated them by asking verbal evaluation questions and made corrections based on their responses. From the results of the evaluation, all the research assistants after the training demonstrated ability to carry out the work. The role of the researchers was mainly supervisory.

In order to avoid interference of extraneous variables with the experiment, it was also necessary to control some extraneous variables such as laboratory state (the quantity of available laboratory materials) and teacher qualification in view of previous research of Akpoghol (2001) and that of Ihuarulam (2008) which indicated that laboratory state and teacher qualification contributed significantly to students' learning outcome in science subjects. It was ensured that all the research assistants used are first degree holders in chemistry and only schools that have well equipped laboratories were used to carry out the study. The research assistants administered the PCAT first as the pre-test and collected the same on the first day before treatment started. The experimental group and the control group had their tests on the same day to avoid interaction. The PCAT was marked by the researcher using the marking scheme and the scores recorded.

In the experimental group, one of the research assistants trained taught one of the intact classes while the other intact class was taught by the other trained research assistant. The teachers of the experimental group incorporated error analysis while teaching. While in control group, the teachers taught chemistry practical using laboratory method only. The same practical topics were covered by both groups. The first three weeks were used for teaching topics on quantitative analysis while the last three weeks were used for teaching topics on qualitative analysis .Students were expected to participate actively in the lesson. At the end of the 6 weeks treatment PCAT was administered as post test to the experimental and control groups.

4. RESULTS

4.1. Research Question One

How would the effect of incorporating error analysis approach on students' achievement differ when compared with those taught using laboratory method?

The result of data analysis to answer this research question is as presented in Table 1.

Table-1. Mean and Standard Deviation for Pre and Post Chemistry Achievement Test for Control and Experimental Groups

Group		PrePCAT	PostPCAT	Mean gain
Control Group	Mean	23.7206	24.4559	0.7353
	N	68	68	
	Std. Deviation	9.11428	10.36561	
Exper Experimental Group	Mean	24.0156	76.0937	52.0781
	N	64	64	
	Std. Deviation	9.11565	12.76244	
Mean Difference		0.2950	51.6378	51.3428

Table 1 shows that both the experimental and control groups had low and almost the same prePCAT mean scores of 24.0156 and 23.7206 respectively. Experimental group had postPCAT mean score of 76.0937 while the control group had 24.4559. The Table also shows that the (post test) achievement scores of the experimental group is higher than that of the control group. The mean gain of the experimental group was found to be higher than that of the control group (52.0781 and 0.7353 respectively). The mean gain difference was found to be 51.3428 in favour of the experimental group which is appreciably high. To ascertain if the difference in achievement was significant hypothesis one was tested.

4.2. Hypothesis One

There is no significant difference in the mean achievement scores between those taught chemistry practical by incorporating error analysis and those taught using conventional method (laboratory method).The result of data analysis to test hypothesis 1 is as presented in Table 1.

Table-2. ANCOVA Test of Between-Subjects Effects for Students' Score in Chemistry Achievement Test in Control and Experimental Groups

Source	Type III sum of squares	df	Mean square	f	Sig.	Remarks
Corrected Model	88133.713	4	22033.428	162.318	.000	S
Intercept	45590.186	1	45590.186	335.858	.000	S
PrePCAT	91.331	1	91.331	.673	.414	NS
Group	86915.226	1	86915.226	640.296	.000	S
Sex	14.366	1	14.366	.106	.745	NS
Group *Sex	110.953	1	110.953	.817	.368	NS
Error	17239.279	127	135.742			
Total	28707.000	132				
Corrected Total	105372.992	131				

a. R Squared= .836 (Adjusted R Squared= .831)

Table 2 shows that there is a significant difference in students' achievement between the experimental and control groups. The calculated F value of 640.296 is significant at 1 and 131 degrees of freedom because p value of 0.0001 is less than 0.05 ($p=0.0001<0.05$) alpha value. The null hypothesis is therefore rejected. There is therefore a significant difference between the mean achievement scores of students taught chemistry practical by incorporating error analysis and those taught using conventional method (laboratory method).

4.3. Research Question Two

To what extent is the difference between the achievement of boys and girls taught chemistry practical by incorporating error analysis approach.

Table-3. Mean and Standard Deviation for Pre and Post Chemistry Achievement Test Score for Male and Female Students in Experimental Group

Sex		PrePCAT	PostPCAT	Mean Gain
Male	Mean	23.3667	76.6333	53.2666
	N	30	30	
	Std Dev	8.1811	14.3333	
Female	Mean	24.5882	76.6176	52.0294
	N	34	34	
	Std Dev	9.9548	11.3858	
Mean diff		1.2215	0.0157	1.2327

Table 3 shows that both boys and girls had low prePCAT mean scores of 23.3667 and 24.5882 respectively. After exposure to incorporating error analysis teaching approach both boys and girls had a higher postPCAT mean score of 76.6333 and 76.6176 respectively. The mean gain for boys and girls are 53.2666 and 52.0294 with a difference of 1.2327 in favour of male students. This result indicates very low difference between male and female students.

4.4. Hypothesis Two

There is no significant difference between the mean achievement scores of boys and girls taught practical chemistry using error analysis approach.

Table-4.ANCOVA Test of between-Subject Effects for Male and Female Students' score in Chemistry Achievement Test experimental Group

Source	Type III Sum of Squares	Df	Mean square	F	Sig
Corrected Model	40.9029a	2	20.471	.1223	0.885
Intercept	47997.105	1	47997.105	286.466	.000
PrePCAT	24.501	1	24.501	.146	.703
Sex	13.701	1	13.779	.082	.5775
Error	10220.496	61	167.549		
Total	380838.0006	64			
Corrected Total	10261	63			

Table 4 shows that the calculated F value of 0.082 was not significant at 1 and 63 degrees of freedom because p value of 0.775 is more than 0.05 ($p=0.775>0.05$) alpha value. This implies that there is no significant different between the mean achievement scores of boys and girls taught practical chemistry using error analysis approach. The null hypothesis was therefore not rejected meaning that gender is not a significant factor when error analysis teaching strategy is used in chemistry.

5. DISCUSSION

It is found in this study that students in the experimental group exposed to incorporating error analysis approach achieved higher than the students in the control group that were exposed to normal laboratory method. Thus there was a significant difference between the achievements of students thought using incorporating error analysis approach when compared with those taught using laboratory method. The reason for this better achievement in chemistry by the experimental group may be linked to what Hebden (2005) found when he said that incorporating error analysis in teaching chemistry enhances learning.

This result confirms what Udoka (2002) found in his research that incorporating error analysis in selected topics in chemistry led to higher achievement in senior secondary school chemistry. Thus incorporating error analysis is found to be an effective method for chemistry teaching at the senior secondary school. It also leads to meaningful teaching as observed by Bichi (2002) when he said that when teaching is effective and meaningful to students/learners, it promotes understanding. Another finding shows that boys in the experimental group had a negligible higher mean achievement score than the girls. The difference was found to be insignificant when the hypothesis was tested. This implies that gender is not a significant factor in students' chemistry achievement in secondary school when error analysis approach is used in teaching. This means that both male and female students under the same condition achieved equally well in chemistry. The reason for this is may be what Dimitrov (2002), and Duguryil (2004) found when they said that poor performance or high performance in sciences is common to both male and female students. Another reason may be in line with what Ibem (2006) said, that is, incorporating error analysis strategy was found to be gender friendly. This finding actually confirms the finding of Udoka (2002), that under the use of incorporating error analysis approach, no significant difference is found among male and female students in secondary school in their academic performance. These findings have far reaching implications for teaching and learning of chemistry practical at the secondary school level in Nigeria. For instance, if time could be taken by chemistry teachers to use this method, there is a likelihood of saving chemicals and hence money because a few practicals may be sufficient to guarantee understanding. Secondly, it may lead to sudden increase in percentage of candidates with credit at SSCE level thereby leading to improved enrolment in the subject both at secondary and tertiary institutions. Thirdly, the traditional laboratory method has become boring as there is no known variety of methods for conducting practical among teachers. It implies therefore that this strategy could be motivating leading to improved interest and therefore high achievement in chemistry practical as found in this study.

6. CONCLUSION

Incorporating error analysis approach is found to facilitate practical chemistry achievement. However, there was no gender disparity in achievement among students exposed to error analysis approach at the secondary school level. If the right method is employed for teaching, it is hoped that both boys and girls will continue to perform equally well in their chemistry career especially chemistry practical.

7. RECOMMENDATIONS

The following recommendations are made based on the findings of this work.

1. Incorporating error analysis proach is suitable for senior secondary school students. Curriculum planners and implementers should therefore recommend it as a teaching method. Consequently, the Government through the Federal and State Ministries of Education should organize and sponsor participant (teachers) to workshops and seminars for training teachers on the use of incorporating error analysis approach.
2. Teacher training institutions like Colleges of Education, Faculties of Education of Universities should train pre-service teachers in the use of incorporating error analysis approach.
3. Error analysis approach is gender friendly as it does not discriminate in its effect on students' achievement. Both male and female learners should be given equal opportunities.
4. Teachers whose subjects' areas have practicals should be motivated not to restrict themselves to the subject contents only but teach practical along with incorporating errors also.

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