IOSR Journal of Research & Method in Education (IOSR-JRME)
e-ISSN: 2320–7388,p-ISSN: 2320–737X Volume 5, Issue 6 Ver. I (Nov. - Dec. 2015), PP 58-65
www.iosrjournals.org

Correcting Students' Chemical Misconceptions based on Two Conceptual change strategies and their effect on their achievement.

Adzape, J.N[1] and Akpoghol, T.V[2**]
[1]*Government Girls College, Makurdi, Nigeria.*
[2]*Chemistry Department, Benue State University, Makurdi, Nigeria.*
[**]*Corresponding Author* – timversh@yahoo.com

Abstract: *The purpose of the study was to correct students' misconceptions using constructivism and analogy as instructional technique and to evaluate the effect on achievement. The participants in the study included 66 SSII Chemistry Students from two intact classes of a chemistry course instructed by the researchers. One class was randomly assigned as the experimental group, and was instructed with constructivism and analogy approach; the other class was assigned as control group and was instructed with lecture method. Chemical Concept Achievement Test (CCAT) was administered to the experimental the two groups as pre-test and post test to measure the students' prior knowledge and achievements respectively. The results showed that students in the experimental group performed better than those in the control group, using the t-test statistic at ($P < 0.05$). The correlation coefficient (r) of the pretest and post-test of the experimental group was also significant. It was concluded that teaching by constructivism and analogy was a better way of correcting students' chemical misconceptions. Teachers are therefore, advised to adopt this teaching method. Text writers and curriculum developers are advised to also change their texts and curriculum designs respectively.*

I. Introduction

One of the obstacles to new learning is the misconceptions that students may have about the instructional topic (Geban, 2005). Research studies have shown that student's prior experiences, education environment and world assessment affect their interpretation of observations and concepts (Taber, 2000). As a result, students may come to classroom with some misconceptions toward the instructional subject to be taught. But Geban (2005) observes that textbooks and instructional strategies are not an efficient way of meaningful learning and instruction. Thus, the process of changing the existing conception (i.e. belief, idea or way of thinking) of students is called conceptual change (Niaz, 2005).

Chemistry contributes to existence, culture and quality of life, this implies it should be taught comprehensively and coherently (Yip, 2004). But researchers have showed that students have problems with some chemistry topics. Griffiths (1994) and Hesse & Anderson (1992) identified those topics that lead to misconceptions as; mole concept, chemical equilibrium, acids and bases, electrolysis, the nature of matter, bonding, molecules, chemical and physical changes and intermolecular forces.

Therefore, inquiring into students' conceptions in chemistry has been a research focus of several researchers for many years (Ebenezer & Gaskell, 1995; Ayas&Costu, 2002). Also Griffiths and Preston (1994) have confirmed that science education literature has been filled with studies relating to the identification, explanation and improvement of students' difficulty in understanding science concepts. Such difficulties have been characterized in ways such as misconceptions, alternative frameworks, intuitive knowledge (beliefs), preconceptions, spontaneous reasoning, children's science and naïve beliefs.

No wonder then that failure in chemistry at the Senior School Certificate Examination(SSCE) level has continued to be on the increase (Nnaka&Anaekwe, 2006; Akpoghol, Samba & Asemave, 2013) Studies have indicated that misconceptions in chemistry have been a major factor contributing to failure in the subject (Nahum, Hofstein, Mamlock-Naaman& Bar-Dov, 2004). Much attention has been given in the area of misconceptions by researchers (Ebenezer, 2001; Ayas&Costu, 2002; Fries-Geither, 2003) with no concrete solution. A lot of research is based on diagnosing these misconceptions of students in various topics without actually proffering solutions as to how they can be corrected. However, Liu and Mac-Isaac (2005) have observed that the key to successful science teaching is to identify students' preconceptions and design appropriate learning sequences for students to critically evaluate their conceptions and construct new meanings compatible with current scientific theories.

Different conceptual change strategies have been described by Swafford and Bryan (2000). It is proven that one of the most successful methodologies on refining misconceptions and promoting conceptual change is the use of analogies within instruction (Dagher, 1994; Metsela& Glynn, 1996). Other conceptual change theories also exist and have proved helpful in improving students' conceptual understanding. These include constructivism (Jegede& Taylor, 1998; Collins, 2009) and conceptual mappings (Ahove, 1998). The essence of this research is to investigate how the use of analogy and constructivism would affect the academic achievement of students.

Statement of the Problem

The conceptual demand of chemistry has been established as a contribution to the difficulty of the subject. Other factors have jointly contributed to students' lowachievement in the subject, with misconceptions as one of them. There is therefore urgent need to look for appropriate, suitable and effective instructional strategy to teach chemistry concepts for conceptual change. The goal of most science education researchers is to help teachers and students to teach and learn science subjects in the most appropriate way. Therefore teachers must understand the source of students' misconceptions and learn how to overcome them for improving learning in chemistry.

In this research, two of the conceptual change theories – analogy and constructivism –were employed in correcting students' chemical misconceptions to ascertain their effect on achievement in chemistry.

Objectives of the Study

The objectives of this study were to analyze patterns of, and correct chemical misconceptions of students using two conceptual change theories.

Specifically the objectives include:

(i) To identify students' misconceptions of chemical concepts at secondary school level.
(ii) To apply two conceptual change theories in correcting them.
(iii) To evaluate the students to determine if there is a change in achievement after applying the conceptual change strategies.

Research Questions

The research questions include:

(i) Will the chemical misconceptions of the SS II students differ from the already established ones?
(ii) To what extent will students' achievement after correction differ from those who did not receive corrections?
(iii) What is the difference between achievement scores of male and female students at post-test?

Hypotheses

The hypotheses for this study include:

H_0 1: The achievement scores of students at pre-test will not differ significantly from their achievement scores at post-test, in the experimental group.
H_0 2: There is no significant difference between the mean scores of students' achievement at post-test of those corrected using two conceptual change strategies and those not corrected.
H_0 3: There is no significant difference between achievement scores of male and female students who received corrections based on the two conceptual change strategies.

Research Design

The research design was an experimental study design (quasi-experimental). The pre-test/post-test control group intact class design was adopted in the study. The design is represented symbolically as follows:

Group	Pretest	Treatment	Post-test	
A	→	O_1	X_1	O_2
………………………………………………				
B	→	O_1	X_2	O_3

Where
O_1 is pre-test for the experimental and control groups
O_2 is post-test for experimental group
O_3 is post-test for control group
X_1 is treatment for experimental group
X_2 is treatment for control group

The experimental and control groups were given a pre-test. The experimental group was exposed to the two conceptual change strategies namely; analogy and constructivism while the control group, did not receive these instruction. Later, the two groups were both given a post-test after which their achievement scored were compared.

Population

The population of the study included all the senior secondary two (SS II) students of Jos North Local Government Area of Plateau State.

Sample and Sampling Technique

The sample for the study was 66 students of SS II in the science classes of two secondary schools in Jos North. The schools were Government Senior Secondary School Laranto, Jos and Federal Government College, Zaria Road, Jos. These are State Government and Federal Government owned schools respectively. The schools were selected using the sampling of convenience method. The reason for adopting this method was borne from the fact that most of the secondary schools in Jos do not have a reasonable number of students offering science subjects – hence chemistry at the Senior School level.

The intact classes of both schools were randomly assigned as the experimental and control groups. The classes comprised 32 students in the experimental group and 34 students in the control group.

Instrument for data collection

The instrument constructed for data collection wasChemical Concept Achievement Test (CCAT) which was used as pre-test and post-test. The instrument consisted of twenty five (25) multiple-choice; short structured and open-ended questions each. The multiple choice questions were made up of 10 items structured to reflect chemistry concepts at the secondary school level. Fifteen (15) essay questions comprising short structured questions, fill-in-the-gaps and true or false questions were all mixed up in the essay part. The questions were constructed to reflect students' common misconceptions in the topics covering SS I in chemistry. This was to help the researchers determine exactly the nature of students' misconceptions in these concepts.

Validation and Reliability of the Instrument

The items for the instrument were a collection of questions from standardized and achievement tests of various test bodies such as the West African Examination Council (WAEC) and Unified Tertiary Matriculation Examination (UTME) as well as other researchers. The questions reflected all areas of the misconceived topics covering the SSI and SSII syllabus. The test items were then subjected to experts in science education and measurement and evaluation for scrutiny. Both the content and construct validities were ascertained.

The instruments were pilot-tested on a selected secondary school using 20 SS2 chemistry students to establish reliability.

The split-half method gave a reliability calculated to be 0.75. With this reliability level, the instrument was adjudged adequate for use in the research.

Procedure for Data Collection

The students were administered the pre-test namely CCAT on the first day of the four weeks exercise. This was done with the help of the assistants from both schools. After sharing writing materials to the students, the typed questions were distributed to each of the students who were expected to complete the test within one hour. The test scripts were collected and scored by the researchers immediately so that the scripts could be returned to the students as a feedback.

The teaching exercise lasted for four weeks after which the students were given a post-test. This took place in the third term of the school's calendar year. After four weeks of instruction based on the scheme of work for the topics prepared by the researchers a post-test was administered to the students on the last day of week four. The post-test which lasted for 40 minutes was also conducted with help of the assistants earlier engaged by the researchers. The CCAT was reshuffled and administered as post-test.

II. Method of Data Analysis

The data collected from the study were analyzed as follows:

Research Question 1 was analyzed using percentages. Research Questions 2&3 were answered using the means and standard deviations.

H_01: t-Test for independent samples (separate variance formula).

H_02: t-Test for independent samples (pooled variance formula).

H_03: Independent t-Test.

The formulae for the independent t-Tests are given as:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{(n_1-1)S_1{}^2 + (n_2-1)S_2{}^2}{n_1+n_2-2}\left[\frac{1}{n_1}+\frac{1}{n_2}\right]}}$$ (pooled variance formula)

Where $\bar{X}_1$ = Mean score for experimental group.
$\bar{X}_2$ = Mean score for control group.
S_1^2 = Variance for experimental group
S_2^2 = Variance for control group
n_1 = Sample size of experimental group
n_2 = Sample size of control group.

The critical values were determined from the table of t-distribution at degree of freedom df = $n_1 + n_2 - 2$ and significant level, P = 0.05.

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \qquad \text{(Separate variance formula)}$$

Where $\bar{X}_1$ = Mean score for experimental group.
$\bar{X}_2$ = Mean score for control group.
S_1^2 = Variance for experimental group
S_2^2 = Variance for control group
n_1 = Sample size of experimental group
n_2 = Sample size of control group.

These values enabled the researcher to take both statistical decisions and research conclusion.

Previously, the research questions were answered using mean scores and standard deviations. Also, to buttress the relationship in hypothesis two stated, determination of correlation coefficient was carried out using the computation of Pearson Product-Moment Correlation Coefficient. The formula is stated as:

$$r = \frac{\sum XY}{(\sum X^2)(\sum Y^2)}$$

Where:

r	=	Product-moment correlation coefficient
x	=	Deviation of each score (x) from the mean
y	=	Deviation of each score (y) from the mean
$\sum$	=	Summation of

The degree of freedom n – 2 was used to determine the critical value. The significance of r was determined using the t-value. This is given as:

$$t = r\sqrt{\frac{n-2}{1-r^2}}$$

Where:

t	=	student t-test
r	=	Pearson product-moment correlation coefficient
n	=	Sample number (size).

III. Results and Discussion

The data were statistically analyzed and interpreted to answer the research questions and to test the hypotheses earlier stated.

Research Question One: Will the chemical misconceptions of the SS II students differ from the already established ones?

The test items from the instrument which were misconceived by students from their answers at pretest were selected and presented in table 1 for analysis.

Table 1: Categories of Students' Misconceptions of Chemical Concepts

	Test Items	Students' Misconceptions
2a	Define an element, and give one example.	An element is the smallest particle of an atom. **29** (44%)
2b	Define a compound, and give one example.	A compound is a place where atoms are found. A compound is a mixture of two or more elements, chemically. **22** (33%)
3.	Define or explain the word, orbital.	An orbital is a room where electrons are kept. An orbital is a ring which attracts protons and electrons to an atom. **27** (41%)
6.	Define or explain the concept, mole.	A mole is a particle called molecule. A mole is a combination of two atoms. **19** (29%)
11.	Give two differences between electrolytic cell and electrochemical cell.	The electrochemical cell has a bridge while the electrolytic cell does not. **8** (12%)
13.	What is rusting?	Rusting is when a metal decays. **25** (38%)

- Numbers in bold face indicate number of students who misconceived the test items.

A look at Table 1 shows that students still misconceived concepts which have been established from other research studies. Students have also manifested new misconceptions of the chemical conceptions already established. As an example, students' definition of a compound as stated in Table 1 showed that they still have not understood the difference between a 'compound' and a 'mixture'. Unfortunately, this definition was given by about 40% of students in all the schools involved in the study (i.e. the experimental, control and pilot study groups).

Research Question Two: To what extent will students' achievement after corrections differ from those who did not receive corrections?

To answer this question, the raw score totals, means and standard deviations of the two groups – experimental and control, are presented in Table 2.

Table 2: Raw Scores, Means and Standard Deviations of Students' Achievement after Corrections (Post Test).

Group	No. of Students	Total Scores	Mean *X*	SD
Experimental	32	1,722	54	16
Control	34	1,482	44	13

Table 2 shows that students who received instructions based on two conceptual change strategies, that is, the experimental group, performed better than those who received instructions based on the traditional method that is the control group. This is evident from the total scores of the experimental group being higher than those of the control group. However, the lower standard deviation of the control group shows that the students' achievement scores are more homogeneous about the mean.

Research Question Three: What is the difference between achievement scores of male and female students at post-test?

The answer to this question is presented in Table 3, based on the total scores, means and standard deviations of the scores.

Table 3: Total Scores, Means and Standard Deviations of Male and Female Students in the Experimental Group, at Post-Test.

Group	No. of Students	Total Scores	Mean *X*	SD
Male	14	810	58	12
Female	18	912	51	19

Looking at Table 3, the total scores of male and female students were 810 and 912 respectively. There was not much difference between the two scores going by the fact that the number of girls in the class was higher than that of boys. The mean scores were also close; therefore the male students did not perform better than the female students. The high standard deviation (19) of the girls as against that of boys (12) also showed that the scores of the girls were more dispersed.

Testing Of Hypotheses

Research Hypothesis One (H_1)

The achievement scores of students at pretest will not differ significantly from their achievement scores at post-test in the experimental group. This hypothesis was tested using two statistical tests; the t-test statistic of dependent samples (separate variance formula) as well as the correlated t-test of significance.

Table 4: t-test Result of the Pretest and Posttest Scores of the Experimental Group.

Group	n	Total Scores	Mean *X*	S^2	SD	df	t-Cal	t-Crit	DecisionP <.05
Pretest	32	812	25	196	14	31	7.200	2.043	Reject null Hypothesis.
Post-test	32	1,722	54	256	16				

Table 4 shows that the calculated t-value of 7.200 while the critical t-value is 2.042. Since the calculated t-value was greater than the critical t-value, the null hypothesis is rejected. This implies that there was a significant difference in the mean scores of the pre-test and post-test at df = 31 and 0.05 significance level. This also clearly showed that students gained significantly from the new method of instruction.

Also, to further buttress the relationship, the product moment correlation coefficient (r) was calculated and found to be 0.93. This was further tested for significance using the t-test statistic of correlation at df = 30 and significance level of 0.05. The calculated value was 13.860 and the critical t-value was 2.042. From the value of r obtained, it showed that there was a significant and positive relationship between the pretest and post-test scores of students. Thus the null hypothesis was rejected.

Research Hypothesis Two (H_2)

There is no significant difference in the mean scores of students' achievement at post-test between those corrected using two conceptual change strategies and those not corrected. This hypothesis was tested using the student t-test statistic of independent samples (pooled variance formula).

Table 5: t-Test Result of the Experimental and Control Groups

Group	N	Total Post Scores	Mean X	S^2	SD	df	t-Cal	t-Crit	DecisionP < .05
Experimental	32	1,722	54	256	16	64	2.79	1.98	Hypothesis Rejected.
Control	34	1,482	44	169	13				

Table 5 shows that the calculated t-value of df = 64 and significance level of 0.05 was 2.79 and the critical t-value is 1.98. The calculated t-value was greater than the critical t-value; therefore the null hypothesis is rejected. This means that there was a significant difference in the mean score of the experimental group as against the control group. This also means that the experimental method of instruction – constructivism and analogy was better than the traditional method in promoting conceptual change in chemistry.

Research Hypothesis Three (H_3)

There is no significant difference between the mean achievement scores of male and female students who received corrections based on the two conceptual change strategies. This hypothesis was also tested using the independent t-test (separate variance formula).

Table 6: t-Test Results Based on Gender Difference

Gender	n	Total Scores	Mean X	S^2	SD	df	t-cal	t-crit	DecisionP > .05
Male	14	810	58	144	12	30	1.27	2.043	Null Hypothesis Retained.
Female	18	912	51	361	19				

Table 6 shows that the calculated t-value was 1.27 and the critical t-value was 2.042. Since the calculated t-value was less than the critical t-value, the null hypothesis was retained. This means that there was no significant difference in the mean scores of male and female students at post-test in the experimental group. However, the values of the variances which were 361 for girls and 144 for boys showed that the achievement scores of boys were more homogeneous than those of the girls. It implies that the abilities of the girls are mixed, with very low achievers and high achievers who could compete with the boys in the class.

IV. Discussion of Results

Discussions are made based on the following

1. Misconceptions of Students. At the end of the analysis, it was discovered that the SS II students of Chemistry still had misconceptions on the same topics as it has been established in literature. Such concepts included elements, compounds, mixtures, atoms, ions, molecules, physical change, chemical change, observation of atoms, entropy, chemical equilibrium, the mole concept, electrolytic and electro-chemical cells, rusting symbols of elements, oxidation and reduction, stoichiometry, kinetic theory, Graham's law and Avogadro's law. This is in line with the works of Hesse and Anderson (1992), Adzape (1995), Gaither (2003), Geban (2005), Calyx, Ayas and Ebenezer (2005), who identified certain concepts as being misconceived by students and teachers of various grade levels and ages.

   In addition to already established misconceptions of students, students in the study revealed new misconceptions as was observed in Table 1. Such misconception as "a compound is a mixture" was not observed in previous studies, nor the definition of an orbital as "a room where electrons are kept". These kinds of misconceptions were observed among 90% of the students in the study.

2. Effect of Constructivism-Analogy Based Instruction. In testing the hypotheses to see if the two conceptual strategies adopted in the study was effective in correcting students' misconceptions, it was discovered that two of the hypotheses proved significant. The results of hypothesis one as shown in Table 4 showed that there was a significant difference between the pre-test and post-test scores of students in the experimental group. A correlation coefficient t-test result further showed that students' post-test achievement was directly related to their pretest achievement. This goes on to show that students who did not do well at pretest,

significantly improved in their achievement at post-test after receiving instructions based on constructivism and analogy. Thus proving that misconceptions were a direct factor affecting their achievement and when these misconceptions were removed or alleviated through corrections, their achievements significantly improved.

This finding is in line with studies by Ayas and Costu (2002), Ebenezer (2001) and Liu and Mac-Isaac (2005), who has established that misconceptions are a hindrance to students' achievement in chemistry.
The results of hypothesis two as shown in Table 5 indicated that a significant difference existed in achievement of students taught with the two conceptual change strategies – constructivism and analogy and those taught with the traditional method. Furthermore, the results of hypothesis two proved that constructivism and analogy based instruction for conceptual change is very effective in facilitating learning. This can make chemistry to wear a human face as observed by Taber (2000).

The results of this hypothesis are in line with the findings of Geban (2005), Bilgin and Geban (2006), Taber (2000), Taylor and Coll (1997) who asserted that conceptual change instructional strategies are very useful in changing students' misconceptions in chemistry. The researcher also discovered that students in the experimental group were very active, excited, and highly motivated to learn. On the other hand, students in the control group were bored, unresponsive and uncooperative. This is because the classroom situation of control group was that of teacher in control, the teacher doing all the talking and the students being passive listeners.

3. Gender Effect. Results of hypothesis three as shown in Table 6 depicted that there was no significant difference between the achievement of male and female SS II students of chemistry who were taught based on constructivism and analogy. This finding implies that there is no gender disparity in chemistry achievement provided both the male and female students are exposed to the same learning task. This finding is in line with the findings of Nsofor (2001), Osedum (2008), Akinbobola, (2005) and Ibe (2006), who concluded that both male and female students perform equally well if exposed to the same condition of teaching.

Nevertheless, the results also showed that students' variances in the two categories were not equivalent. The variance of the female group was very high. This showed that the achievement scores of the female students were not homogenous. There was high disparity in their scores with some scoring very high and others scoring very low. The implication here is that, not all the female students are doing well in chemistry. This is evident from the fact that some of the female students were trying to cheat during the pretest and posttest, by soliciting assistance from their male counterparts, who sat near them.

V. Summary of Findings

The hypotheses were tested and a summary of the findings are as follows:
(a) Students have misconceptions on chemical concepts which have already been established from previous studies.
(b) Students exhibited new misconceptions of chemical concepts other than the already established ones.
(c) Students' achievement was hampered as a result of misconceptions which they had about certain chemical concepts.
(d) Students taught with two conceptual change strategies – constructivism and analogy, performed better than those taught with the traditional method.
(e) Students' achievement at post-test was better than their achievement at pretest in the experimental group.
(f) There was no significant difference in the achievement of male and female students taught by constructivism and analogy.

VI. Conclusion

Conclusions drawn from this study include:
(a) Teaching by constructivism and analogy facilitates learning and enhances the learner to gain more knowledge and understanding of chemical concepts.
(b) Teaching by constructivism promotes the social-cultural background of the students and makes students to actively participate in learning.
(c) There is no disparity in the achievement of males and females in chemistry when they are exposed to the same teaching and learning conditions.

VII. Recommendations

The following recommendations are made:
1. Chemistry teachers should adopt the use of constructivism – analogy based instructional technique.

2. Students' prior knowledge should be evaluated using pretest to analyze their misconceptions before instruction begins.
3. Teaching should be learner centered and not teacher centered. This means that activities should be organized around the learners and the teacher should be a passive participant, supervising the learning activities.
4. Employers should avail the teachers the opportunity to attend seminars and workshops which are organized to promote the conceptual change strategies.
5. The secondary school chemistry curriculum should be organized based on conceptual change strategy to facilitate misconceptions change in students.
6. Text writers should replace the traditional chemistry texts with new conceptual change texts for effective teaching and learning.
7. Female students should not necessarily opt for science based subjects if their abilities are not adequate as they would eventually not perform well.

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