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Comparative Effects of Two Metacognitive Instructional Strategies on Gender and Students' Problem-Solving Ability in Selected Chemistry Concepts

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Abstract:
Successful chemistry learning in secondary schools involves students' ability to solve chemistry problems irrespective of their sex. Metacognitive instructional strategies have been found to be effective in this direction. However, the comparative effects of analogies and concept mapping strategies on male and female students' problem solving ability in tasks involving mole, electrolysis and stoichiometry have not been documented. The study aimed at finding out if male and female students differ in their problem solving ability when taught the three concepts using analogies, concept maps and lecture method. 96 students were randomly selected, pre-tested and assigned into control, and two experimental groups. The control group was taught using lecture method, while the experimental groups were taught using analogy and concept mapping respectively. Three instruments, Chemistry Achievement Test (CAT), Mathematical Skill Test (MST) and Chemistry Problem Solving Test (CPST) were developed and use. Students' posttest mean scores in the CPST were analyzed using t-test and ANOVA (at 0.05 level). Results showed that there were no significant differences between the posttest mean scores of male and female students taught using concept mapping. However, there was a significant difference between the posttest mean scores of the male and female students taught using analogies. In each of male and female groups, there was a significant difference between the students taught with concept maps and those taught with analogies. The study recommended the use of concept mapping strategy for teaching both male and female students problem solving tasks in electrolysis, mole and stoichiometry

Keywords: *Analogy, concept maps, problem-solving, metacognitive instructional strategies, electrolysis, mole, stoichiometry*

1. Introduction

The role of science in the development of a nation cannot be over emphasized. Throughout history, the development of new technology has been vital for human survival and progress (Malik, 2010). Technology is the primary vehicle through which humanity progresses and it serves to eliminate hunger, poverty and lack of access to education in the future. This accounts for the current developments in science and technology which have so greatly affected the lives of humans. The importance of technology lies in the benefits of technology to society (Oak, 2011). 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 plays an important role such that the bulk of the present technological break-through is built on it (Gongden, 1998). It occupies a unique position in science education. Students offering courses such as medicine, biology, pharmacy, physics, biochemistry, microbiology, home economics, etc are required to take chemistry. The knowledge of chemistry is brought to play in the manufacture of products that improves man's luxury such as herbicides, insecticides, plastic products, foams, drugs, clothing materials etc (Oak, 2011). It is a widely held view that the scientific development of any nation is enhanced by the quality of chemical education in its schools (Okafor, 2000). A lot of activities centered on the study of chemistry such as the management of natural resources, manufacturing, processing and storage of food and health facilities and a favorable living environment draw their basis from chemistry as Ezeudu (2000) remarked.

Studies such as Jimoh (2004) and Njoku (2007) amongst others have reported that the performance of chemistry students at the secondary and tertiary levels has been poor and deplorable over the years. Other studies (Crippen, Brooks & Courtright, 2000; Wagner, 2001; Danjuma, 2005) have reported the poor performance of chemistry students in problem – solving tasks. Reports from the National Examination Council (NECO) revealed 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). Table one below reveals that from 2007 to 2011, the highest percentage credit pass was 50.70% in 2010 in the West African Senior School Certificate Examination (WASSCE).

S/No	Year	% of Candidates with Grades 1-6
1	1997	25.30%
2	2001	36.25%
3	2002	34.42%
4	2003	50.98%
5	2006	44.90%
6	2007	45.96%
7	2008	44.44%
8	2009	43.70%
9	2010	50.70%
10	2011	49.54%
11	2012	43.13%

Table 1: Performance of Chemistry Students in the West African Senior School Certificate Examination (WASSCE).
Source: The West African Examination Council (2012)

One of the factors identified as responsible for students' dismal performance is their inability to solve chemical problems (Wagner, 2000; Danjuma, 2005). Some of the concepts that present such difficulty to students include electrochemistry, chemical equilibrium, redox reactions, mole concept and stoichiometry (Cripen, Brooks & Courtright, 2000; Wagner, 2001). Danjuma (2005) noted that several studies have been undertaken on the teaching and learning of problem solving skills with a view to addressing nature and processes of problem solving, instructional strategies (Huffman, 1997) and gender (Eribe & Ande, 2006; Adesoji & Babatunde, 2008). These efforts were aimed at improving problem solving amongst teachers and students. Gabel (2003a) said that the main reason why students are unable to solve problems in science education lies with the method of instruction. 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 suggest the need to find out which instructional strategies can best influence students' problem solving performance in chemistry. Metacognitive instructional strategies have emerged through researches and have proved effective for learning chemistry and science in general (Gabel, 2003b). They include use of analogies and concept mapping strategies.

Metacognitive instructional strategies are instructional methods that help a learner to take charge of their learning through connecting new information to a former knowledge that they already possess. Current trends in chemistry curriculum theorizing involves attempts to present topics such that students are involved in learning and studying them as they build upon knowledge that they already know. Such is the underlying principle behind the theory of constructivism; the theoretical basis of the study. Constructivism is a philosophy (theory) of learning founded on the premise that, by reflecting on our experiences, we construct our own understanding of the world we live in (EBC, 2004). This theoretical framework holds that learning always builds upon knowledge that a student already knows.

An analogy is a comparison between two domains of knowledge: one that is familiar and another that is not (Orgil & Bodner, 2004). The familiar one is called the analog while the unfamiliar one is the target domain. The target is what needs to be learnt. Effective analogies motivate students, clarify students' thinking, help them overcome misconceptions and help them visualize abstract concepts (Orgil & Thomas, 2007). The discussions that occurs when using analogies help students construct their own knowledge and base the instruction on their prior knowledge and existing alternative conceptions. Knowledge is constructed in the mind of the learner and as they construct knowledge, they seek to give meaning to the information they are learning. Some of the abstract and challenging concepts in chemistry can be understood if analogy is used to illustrate the points. A concept map on the other hand, is an instructional strategy that involves graphical or diagrammatic representation of concepts achieved by selecting and arranging them into a meaningful hierarchy to show relationships between levels and among concepts (Olajenbesi & Aluko, 2000). They are graphical tools for organizing and representing knowledge. Concept maps are excellent tools for students to generate meaningful connections between chemical concepts. Francisco, Nakhleh, Nurrenbern and Miller (2002) said evidence abound to show that concept maps can be used to provide students, teachers, professors etc information about students' conceptual understanding. Concept maps have proved to be appropriate means of representing and organizing knowledge in a graphical way, and it helps students construct meaningful learning in an effective way (Aguirre – Perez, 2010). This happens because a learner pulls together information already known about a subject and understands new information as he learns. Concept maps have their origin in the learning movement called constructivism constructivists hold the view that learners actively construct knowledge. By constructing a concept map, one reflects on what you know and what you do not know.

Both analogies and concept mapping have found some useful applications in the teaching and learning of science. A problem solver who is successful in securing a solution will need the adequate translation of the problem's statement, the correct recall of prior knowledge such as rules and facts and making relevant linkage between the problem's statements, rules and facts so that a solution sequence emerges. What remains unclear however is the extent to which each of analogies and concept mapping are influenced by gender and students' problem solving ability in tasks involving mole, stoichiometry and electrolysis.

1.1. Statement of the Problem

The West African Examination Council chief examiners' reports have over the years (1995-2011) pointed the areas of students' problem solving difficulty in chemistry to include the mole, chemical equilibrium, stoichiometry, rates of chemical reactions, electrolysis, oxidation-reduction reactions and thermo chemistry. They report students' shallow understanding of the concepts, inability to tackle numerical problems and poor mathematical skills. The poor problem solving ability of students points to a likely deficiency in method of instruction, a conclusion also drawn by Gabel (2003a). The neglect of students' centred learning strategies has been identified as one of the major reasons for students' poor performance in secondary science education (Ezenwa, 2005). Metacognitive instructional strategies tend to assist in this direction (Foxwell & Menasce, 2004; Orgil & Thomas, 2007). However, despite the effectiveness of these metacognitive instructional strategies, little is understood about their comparative effects especially on male and female chemistry students' problem solving ability. Various studies on gender and students' performance in chemical problem solving tasks (Eribe & Ande, 2006; Jimoh, 2007; Adesoji & Babatunde, 2008) have not even yielded consistent and definitive results. While some research reports indicated that gender has no effect on students' performance in sciences, others reported that it has.

The effects of concept mapping and analogies on male and female problem solving ability in tasks involving the mole, stoichiometry and electrolysis have not been documented especially in Secondary Schools in Plateau state. It is against this background that the study sets out to find out the effect of analogy and concept maps on male and female students' abilities in problem solving in three selected chemistry concepts - the mole, stoichiometry and electrolysis (referred to as MSE in the study).

1.2. Purpose of the Study

The main purpose of this study was to find out the comparative effects of analogy and concept mapping on male and female students' problem solving ability in three chemistry concepts – the mole, stoichiometry and electrolysis. Specifically, the study sets to

i. Find out if male and female students taught with concept mapping strategy differ in their problem solving ability in tasks involving mole, stoichiometry and electrolysis.
ii. Find out if male and female students taught with analogy teaching strategy differ in their problem solving ability in tasks involving mole, stoichiometry and electrolysis.
iii. Find out if male students taught mole, stoichiometry and electrolysis in the analogy, concept mapping and control groups differ in their problem solving ability in tasks involving mole, stoichiometry and electrolysis.
iv. Find out if female students taught mole, stoichiometry and electrolysis in the analogy, concept mapping and control groups differ in their problem solving ability in tasks involving mole, stoichiometry and electrolysis.

The following research questions were investigated during the study in order to help accomplish the purpose of the study.

i. What is the difference between the posttest mean scores of male and female students in a chemistry problem solving test when taught mole, stoichiometry and electrolysis using concept mapping instructional strategy?
ii. What is the difference between the posttest mean scores of male and female students in a chemistry problem solving test when taught mole, stoichiometry and electrolysis using analogy instructional strategy?
iii. What is the difference between the posttest mean scores of male students in a chemistry problem solving test involving mole, stoichiometry and electrolysis in the control, analogy and concept mapping groups?
iv. What is the difference between the posttest mean scores of female students in a chemistry problem solving test involving mole, stoichiometry and electrolysis in the control, analogy and concept mapping groups?

1.3. Research Hypotheses

The following null hypotheses were tested during the research in order to answer the research questions:

i. There is no significant difference between the posttest mean scores of male and female students in a chemistry problem solving test when taught mole, stoichiometry and electrolysis using concept mapping instructional strategy.
ii. There is no significant difference between the posttest mean scores of male and female students in a chemistry problem solving test when taught mole, stoichiometry and electrolysis using analogy instructional strategy.
iii. There is no significant difference between the post-test mean scores of male students in a chemistry problem solving test in the analogy, concept mapping and control groups.
iv. There is no significant difference between the post-test mean scores of female students in a chemistry problem solving test in the analogy, concept mapping and control groups.

2. Materials and Methods

The study was a pretest-post-test control group design. A pretest was given in order to measure the initial behavior of the groups before treatment was administered to them (Sambo, 2005). 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 average different scores were compared in order to ascertain whether the experimental treatment produced a greater change in the experimental groups over the control that was not exposed to any treatment. 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. It also ensures that both groups are equivalent on all important dimensions and that there are no systematic differences between the two groups (Trochin, 2006). The design also controls all the threats to internal validity.

The design is diagrammed as follows:

G_1: → R → Y_{11} → X_1 → Y_{12}
G_2: → R → Y_{21} → X_2 → Y_{22}
G_3: → R → Y_{31} → X_3 → Y_{32}

Where:
X_1, X_2 and X_3 = independent variables (analogy, concept map and lecture methods)
G_1, G_2, G_3 = analogy, concept mapping and control groups respectively
R = random allocation of subjects
Y_{11}, Y_{21} and Y_{31} = pretest results of analogy, concept mapping and control groups respectively
Y_{12}, Y_{22} and Y_{32}= dependent variable (performance of students in chemistry problem solving test), that is, posttest results of analogy, concept mapping and control groups respectively.

Group	SS	Pretest	IS	Posttest
G_1	n_1	CPST	analogy	CPST
G_2	n_2	CPST	concept mapping	CPST
G_3	n_3	CPST	lecture	CPST

Table 2: The Pretest-Posttest Control Group Design

Where:
1= group of students taught using analogy (male and females)
2=group of students taught using concept mapping (males and females)
3=group of students in the control (males and females)
SS= sample strength
CPST= chemistry problem-solving test
IS= Instructional strategy
Analogy and concept mapping are instructional strategies, the treatment to be given.

2.1. Population and Sample of the Study

The senior secondary two chemistry students (2012/2013) in Plateau state (Nigeria) formed the population of the study. The assumption is that they might have been taught the three concepts – stoichiometry, mole and electrolysis. Three schools were sampled from the Plateau North zonal directorate through simple random sampling.

In order to get the student sample that will be equivalent (equality of groups), two instruments – the Chemistry Achievement Test (CAT) and Mathematics Skills Test (MST) were used. The use of the CAT and the MST ensured that only those who have some basic knowledge in chemistry and basic mathematical skills were chosen for the research. 32 students (16 males and females each) were randomly selected from each of the schools. The selection of 32 students from each of the schools gave the study sample of 96 students (48 each of male and female students). Randomization also helped establish the equality of the groups.

The main data for the research was collected using the Chemistry Problem Solving Test (CPST). This was used to find out the problem solving ability of the students. This is necessary because chemistry functions best at problem solving (Danjuma, 2005). It consisted of three questions, one each drawn from the concepts taught (electrolysis, stoichiometry and the mole). The validity and reliability of the CPST, CAT and MST were all established through pilot testing and PPMC. The Pearson Product-Moment Coefficient (PPMC) coefficient of the CPST, CAT and MST were found to be 0.87, 0.80 and 0.93 respectively.

The students were pretested after which they were taught the three chemistry concepts (MSE) in the schools assigned to each of them. This spanned over a period of five weeks. The same lesson plans were used for each group. Concept maps and analogies were used appropriately in the concept mapping class and analogy group respectively. None was used in the control group. A posttest was administered to each class at the end of the five weeks of instruction.

3. Results

The data collected from the administration of the CPST were analyzed using t-test and one-way analysis of variance (ANOVA). The researcher assumed equal variances in the scores (performance) of both male and female students and for the two instructional strategies. Results obtained were compared at 0.05 level of significance

Analysis of data shows that there is no significant difference between the pre-test mean score of male students and that of female students in a chemistry problem solving test. The p-significant value was found to be 0.675 ($p > 0.05$).

3.1. Research Question One

What is the mean difference between the posttest mean scores of male and female students in a chemistry problem solving test when taught using concept mapping instructional strategy?

Group	N	Mean score	Standard error	Mean diff.
Male	16	75.00	0.658	1.90
Female	16	73.10	0.403	

Table 3a: Group Statistics of Posttest Mean Scores of Male and Female Students in a CPST involving MSE when Taught with Concept Mapping

The posttest mean score of male students in the concept map group was 75.00 while that of the female students in the same concept map group was 73.10. The posttest mean difference was 1.90 (table 3a). The difference was not much.

3.2. Research Hypothesis One

There is no significant difference between the posttest mean scores of male and female students in a chemistry problem solving test when taught using concept mapping instructional strategy.

	Mean diff.	T	df	Standard error diff.	P-sig (2-tailed)
Equal variance assumed	1.90	0.729	30	0.772	0.472

Table 3b: Independent Sample Test for Equality of Means of Male and Female Students in a CPST involving MSE when taught with Concept Mapping

The p-value, 0.472 > 0.05. This indicated that there was no significant difference between the posttest mean scores of male and female students in a chemistry problem solving test when taught using concept mapping instructional strategy. Hypothesis one (null) was therefore retained.

3.3. Research Question Two

What is the difference between the post test mean scores of male and female students in a chemistry problem solving test when taught using analogy instructional strategy?

Group	N	Mean score	Standard error	Mean diff.
Male	16	66.00	0.593	6.60
Female	16	59.40	0.518	

Table 4a: Group Statistics of Posttest Mean Scores of Male and Female Students in a CPST involving MSE when Taught Using Analogy.

The results analyzed and presented in tables 4a showed that the mean difference was 6.60, the mean scores of male students being higher than females'.

3.4. Research Hypothesis Two

There is no significant difference between the posttest mean scores of male and female students in a chemistry problem solving test when taught using analogy instructional strategy.

	Mean diff.	t	df	Standard error diff.	p-sig (2-tailed)
Equal variance assumed	6.60	2.539	30	0.788	0.017

Table 4b: Independent Sample Test for Equality of Means for Male and Female Students in a CPST involving MSE when taught with Analogy

The p-value, 0.017 < 0.05 as presented in table 4b. This showed that the mean score of male students in the CPST when taught with analogy differed significantly from that of the female students. The null hypothesis was rejected and the alternate hypothesis accepted. Therefore, there is a significant difference between the posttest mean scores of male and female students in a chemistry problem solving test when taught using analogy instructional strategy.

3.5. Research Question Three

What is the difference between the posttest mean scores of male students in a chemistry problem solving test in the analogy, concept mapping and control (lecture method) groups?

Group	N	Mean score	Minimum	Maximum
Control	16	54.60	36.70	70.00
Analogy	16	66.00	53.30	80.00
Concept map.	16	75.00	60.10	86.7%
Total	48	65.20	50.00	78.90

Table 5a: Posttest Mean Scores of Male Students in Control, Analogy and Concept Mapping Groups in a CPST involving MSE.

From the posttest mean scores of the male students (in Table 5a), it is clear that the performances of the male students in the posttest differ from one group to the other. The differences in the posttest mean scores of the groups are: concept mapping – analogy (09), concept map – control (20.4), analogy – control (11.4).

3.6. Research Hypothesis Three

There is no significant difference between the post-test mean scores of male students in a chemistry problem solving test in the analogy, concept mapping and control groups.

Source	Type III sum of squares	df.	Mean square	F	p-sig.
Intercept	18369.187	1	18369.187	2699.697	0.000
Group H_03	301.625	2	150.813	22.165	0.000
Error	306.188	45	6.804		
Total	18977.000	48			
Corrected Total	607.812	47			

Table 5b: ANOVA of Posttest Mean Scores of Male Students in a CPST involving MSE in Control, Analogy and Concept Mapping Groups (Between Subjects Effects)

a. R squared = 0.496 (Adjusted R squared = 0.474).

The ANOVA carried out on the mean scores (in Table 5b for within groups and between subjects) yielded p-values of 0.000, $p < 0.05$. The analysis showed that there was a significant difference between the posttest means scores of the male students in control, analogy and concept mapping groups. The null hypothesis was rejected and the alternate accepted. Therefore, there was a significant difference between the posttest mean scores of male students in a chemistry problem solving test in the control, analogy and concept mapping groups.

Pair wise multiple comparison test gave a mean difference value of concept mapping-analogy (9.00), concept mapping-control (20.40) and analogy-control (11.40). The source of difference is significant among the groups. There was a significant difference in favour of concept mapping-control group. The multiple comparison tests showed that concept mapping accounts more for the variation in the male students' performance than the control (table 5c). Table 5d shows that at $p < 0.05$, concept mapping significantly contributed more to the source of the difference that existed among the groups.

Group (i)	Group (j)	Mean diff. (i-j)	Standard error	Sig.
Concept mapping	Analogy	9.00*	0.922	0.020
	Control	20.40*	0.922	0.000
Analogy	Concept mapping	-9.00*	0.922	0.020
	Control	11.40*	0.922	0.002
Control	Analogy	-11.40*	0.922	0.000
	Concept mapping	-20.40*	0.922	0.002

Table 5c: Scheffe Pair Wise Multiple Comparison Test (Posttest Male) in a CPST involving MSE.

*The mean difference is significant at the 0.05 level in all cases.

Scheffe[a] Mean order	N	Subset1	Subset 2	Subset3
Control	16	54.60		
Analogy	16		66.00	
Concept mapping	16			75.00

Table 5d: Scheffe's Test (Male posttest) in a CPST involving MSE

3.7. Research Question Four

What is the mean difference between the post-test mean scores of female students in a chemistry problem solving test in the analogy, concept mapping and control groups?

Group	N	Mean score	Minimum	Maximum
Control	16	53.80	40.00	73.30
Analogy	16	59.4	50.00	76.70
Concept mapping	16	73.10	63.30	83.30
Total	48	62.10	51.10	77.77

Table 6a : Posttest Mean Scores of Female Students in Control, Analogy and Concept Mapping Groups in a CPST involving MSE.

The differences in the posttest mean scores of the groups are: concept mapping – analogy (13.7), concept map – control (19.3), analogy – control (5.6). As in the case of their male counterparts (Table 6a), the female students exposed to concept mapping performed better than those exposed to analogy who also performed better than those exposed to lecture or traditional method.

3.8. Research Hypothesis Four

There is no significant difference between the post-test mean scores of female students in a chemistry problem solving test in the analogy, concept mapping and control groups.

Source	Type II sum of squares	df	Mean square	F	p-sig.
Intercept	16650.750	1	16650.750	3419.435	0.000
Group H_04	286.125	2	143.063	29.380	0.000
Error	219.125	45	4.869		
Total	17156.10	48			
Corrected total	505.250	47			

Table 6b: ANOVA of Posttest Mean Scores of Female Students in a CPST involving MSE in the Control, Analogy and Concept Mapping groups (test of between subject effects)

a. R squared = 0.566 (Adjusted R. Squared = 0.547)

Group (i)	Group (j)	Mean diff (i-j)	Standard error	Sig.
Concept mapping	Analogy	13.70*	0.780	0.000
	Control	19.30*	0.780	0.000
Analogy	Concept mapping	-13.70*	0.780	0.000
	Control	5.60	0.780	0.108
Control	Concept mapping	-19.30*	0.780	0.000
	Analogy	-5.60	0.780	0.108

Table 6c : Pair Wise Comparison Test (Female Posttest) in a CPST involving MSE

Scheffe[a] Mean order	N	Sub-set1	Sub-set2
Control	16	53.80	
Analogy	16	59.40	
Concept mapping	16		73.10

Table 6d: Scheffe's Test (Female Posttest) in a CPST involving MSE

Results of the analysis presented in table 6b yielded P-values of 0.000, less than 0.05 alpha levels (a 99.9% significant difference). The null hypothesis was rejected in favor of the alternate hypothesis. Therefore, there was a statistically significant difference between the posttest mean scores of female students in a chemistry problem solving test in the control, analogy and concept mapping groups. A pair wise comparison test carried out to find the source of variation gave the following results in tables 4c and 4d.

Based on the observed means, the error term (mean square) is 4.869 (Table 6b). The value of the mean difference of concept mapping-analogy was 13.70, concept mapping-control (19.30) and analogy-control (5.60). The source of difference is significant among the groups at the 0.05 level except for the control-analogy pair where there's no significant difference, $p = .0108$, $p > 0.05$. Concept mapping again showed itself as an instructional strategy that has more effect on female students' performance in chemistry problem solving test than control and analogy. Table 6d again shows concept map group mean score showing significant difference from the analogy and control groups.

4. Discussion of Results

A major finding of this study was that no statistically significant difference occurred between the posttest scores of male students and that of female students in a chemistry problem solving test involving electrolysis, stoichiometry and mole, when they were taught with concept mapping. This means that the use of concept mapping in teaching electrolysis, stoichiometry and mole concepts is not influenced by gender. This was similar to the findings of Adesoji and Jimoh's (2007) that gender has no effect on students' performance in chemistry questions, a position earlier held by Inyang and Jegede (1991). Erinosho in Adesoji and Babatunde (2008) also found out that gender difference had no influence on students' performance in chemistry and science examinations. Schmitz and Grunau (2009) specifically found out that concept mapping meets females' demands to a higher degree and hence they are able to perform better in concept mapping tasks like their male counterparts. This study showed that through the use of concept mapping instructional strategy both male and female chemistry students can be helped to do better in problem solving tasks especially in the mole, stoichiometry and electrolysis. Gender difference and influence can therefore be taken care of since concept mapping proved to be a better strategy. The finding is at variance with that of Adesoji and Babatunde (2008) and Shuaibu and Mari (1997) who found out that female students performed better than male students in chemistry problem solving tasks (though with no reference to concept mapping). The result of this study disagreed with this claim as the performance of females in chemical problem solving depends on the instructional strategy with which they are taught. The non – existence of a statistically significant difference in the post-test mean scores of males and females may be due to the advantage that concept mapping presents to all students as Olajenbesi & Aluko (2000) once noted. Gabel (2003b) stated that concept maps help students to focus on the relationships among concepts for long time, relating them to one another. Meaningful connections between chemical concepts ensure a significantly better acquisition of science concepts (Uzuntiryaki & Gedan, 2005) which further enhances problem solving ability (Francisco, Nakhleh Nurrenbern and Miller 2002).

The study found out that there was a statistically significant difference between the posttest means score of male and female chemistry students in chemistry problem solving test when taught with analogy. The male chemistry students benefitted more in problem solving task involving the mole, stoichometry and electrolysis when taught using analogy than female students. There is a gender influence here on the ability to solve chemical problems when students are taught using analogy. The reason for this may be the fact that male students have better reasoning ability than females. Males are also generally exposed to situations/the environment more than females. This makes them familiar with a lot of things/processes such that when they are used as analogies, they understand them better than females. The customs of most people in Nigeria encourage women to stay away (but indoors) from exposure or participation in storytelling, sitting in the market square to discuss, etc. Males easily visualize abstract concepts in relation to analogies as a result of their day to day experience in life. The female students misconceived the analogy used more than the males thereby misapplying the analogy. The finding is in line with Eribe and Ande's (2006) who had earlier found out that there exists gender difference or inequality in science achievement among secondary school science student's world over with male students tend to score higher than female students. Onekutu (2002) had also found that male students performed better than females with an increasing gap in chemistry examination (though with no reference to teaching strategies and problem solving). Adesoji and Babatunde (2008) found out that female students encountered problem solving difficulties more frequently than their male counterparts in inorganic chemistry. Armagan, Sagir and Celik (2009) however reported a situation in favour of females when they investigated the effect of problem solving skills on the achievement of male and female chemistry students. Olorundare and Aderogba (2009) on the other hand, found that no significant difference occurred between the academic performance of male and female students exposed to treatment with analogy. They however, reported that the ability levels of the students influenced their performance. The report of this study as it relates to gender and problem solving disagreed with their findings as male students performed better than females in problem solving tasks involving the mole, electrolysis and stoichiometry when taught using analogy.

The male students in concept mapping class performed better than their counterparts in analogy who also performed better than the control group in problem solving task involving the mole, electrolysis and stoichiometry. There was a significant difference in the posttest mean scores of the male students when taught problem solving task involving the mole, electrolysis and stoichiometry with concept mapping, analogy and lecture. A similar trend was observed with the female students in problem solving task involving the mole, electrolysis and stoichiometry. However, while there was a significant difference in the posttest of female students in concept mapping and those in analogy, there was no significant difference between the posttest means scores of the female students taught with analogy and those in the control. The source of difference was significant among the groups at the 0.05 level except for the control-analogy pair (for females) where there's no significant difference.

In all the results, concept mapping proved effective than analogy in enhancing students' problem solving ability in tasks involving the mole, stoichiometry and electrolysis. The finding concerning concept map's effectiveness over analogy agrees with earlier finding by Olorundare and Aderogba (2009) who compared the effects of concept mapping, analogy and expository strategies on secondary school students' performance in chemistry task involving particulate nature of matter, chemical combinations and the gaseous state. They found out that students exposed to concept mapping performed better than those exposed to analogy that also performed better than those exposed to expository method. Duit, Roth, Komorek & Wilbers (2001) once noted that analogy has the tendency to mislead students' learning process and generate confusion and misconception. This misconception affects problem solving ability. Some students may resort to a mechanical use of analogy without considering the information the analogy is meant to convey (Orgil & Bodner, 2004). No wonder the non significant difference in the control-analogy pair (for females). The finding is inconsistent with that of Fechner and Sumfleth (2008) who stated that the effects of concept maps is chemistry are generally small and that students taught in concept map groups do not perform better than those in control groups.

5. Conclusion

The study showed that concept mapping strategy helps improve chemistry students' performance in problem solving tasks involving mole, stoichiometry and electrolysis than the use of analogies. Both male and female students benefit well from instruction using concept mapping as it help to show relationship between levels and concepts thereby helping students to focus on the relationships among concepts for long time. Male students however, benefit more than female students in chemistry problem solving test when analogy is used to teach the concepts of mole, stoichiometry and electrolysis.

The result of this study has implication for the teaching and learning of chemistry in secondary schools. The findings show that teaching strategies influence the performance of students in problem solving tasks involving mole, stoichiometry and electrolysis. The findings here also revealed that problem solving ability of male and female students would be better improved if they are exposed to concept mapping rather than analogy. Chemistry teachers are encouraged to embrace concept mapping strategy to teach concepts such as the mole, stoichiometry and electrolysis in mixed gender and ability classes in order to improve students' problem solving ability. Chemistry teachers' training programs should include a deliberate preparation of teachers for the acquisition of skills in the use of concept maps and other metacognitive strategies that are useful in this direction. Education authorities and professional bodies should organize seminars, workshops, refresher courses and conferences on the construction and use of concept mapping as an instructional strategy on regular basis for teachers.

6. References

i. Adesoji, F. A., & Babatunde, A. G. (2008). Investigating gender difficulties and misconception in inorganic chemistry at the senior secondary Level. International Journal of African and African- American Studies, 7 (1). Retrieved May 30, 2014 from www.ojcs.siue.edu

ii. Armagan, D., Sagir, S. U., & Celik, A.Y. (2009). The effects of students' problem solving skills on their understanding of chemical rates and their achievement on this issue. Procedia Social and Behavioural Sciences, 1 (1), 2678 - 2684.

iii. Crippen, K. J., Brooks, D.W., & Courtright, R.D. (2000). Mole mapping. Science Teacher, 67 (7), 36-39.

iv. Danjuma, I. M. (2005). An investigation of pre-service NCE teachers' numerical chemical problem solving behaviours. Unpublished doctoral thesis, A.T.B.U Bauchi.

v. Educational Broadcasting Corporation. (2004). Constructivism as paradigm for teaching and learning. Retrieved May 28, 2014 from http://www.thirteen.org/edonline/concept2 class/constructivism/

vi. Eribe, J. O. & Ande, S. (2006). Gender difference in achievement in calculating reacting masses from chemical equations among secondary school students in Makurdi metropolis. Educational Research and Reviews, 1 (6), 170-173.

vii. Ezenwa, V. I. (2005). Concept Mapping: a Veritable Tool in Science Education. Inaugural Lecture, Federal University of Technology Minna.

viii. Ezeudu, F. O. (2000). The use of local material in the teaching of chemistry. Proceedings of the 41st Conference of the Science Teachers' Association of Nigeria, 163-165.

ix. Fechner, S., & Sumfleth, E. (2008). Collabrative concept mapping in context oriented chemistry learning. In A. J. Canas, P. Reiska, M. Ahlberg and J. D. Novaks (Eds), Proceedings of the Third International Conference on Concept Mapping (pp289). Tallin, Estonia & Helsinki, Finland. Retrieved January, 28 2012 from cmc.ihmc.us/cmc2008papers/cmc

x. Foxwell, H. J., & Menasce, D. A. (2004). MARVIN: A web- based system for representing, retrieving and visualizing analogies. World Wide Web, 7 (4), 385 – 419.

xi. Francisco, J. S., Nakhleh, M. B., Nurrenbern, S. C., & Miller, M. L. (2002). Assessing student understanding of general chemistry with concept mapping. Journal of Chemical Education, 79 (2), 248–250.

xii. Gabel, D. (2003a). Problem solving in chemistry: Research matters to the science teacher. Retrieved June, 12 2013 from www.narst.org/publications/research/problem.cfm

xiii. Gabel, D. (2003b). Enhancing the conceptual understanding of science. Educational Horizons, Winter Edition, 70 -76.

xiv. Gongden, E. J. (1998). Analysis of the senior secondary two chemistry syllabus to determine areas of difficulty. Unpublished master's thesis, University of Jos.

xv. Huffman, D. (1997). Effect of explicit problem solving instruction on high school students' problem solving performance and conceptual understanding of physics. Journal of Research in Science Teaching, 36 (6), 337-379.

xvi. Inyang, N., & Jegede, O. J. (1991). Development, validation and standardization in Integrated science among secondary school students. International Review of Education, 36 (3), 310-319.

xvii. Jimoh, A. T. (2004). Influence of gender difference on students' achievement in chemistry. Nigerian Journal of Educational Studies and Research, 2 (1), 88-94.

xviii. Jimoh, A. T. (2005). Comparison of students' achievement in the four categories of questions in analytical chemistry at the degree level. Ilorin Journal of Education, 27, 38-43.

xix. Malik, A. (2010). Technology and developing countries. Retrieved July 18, 2014 from http://amalik17.blogspot.com/2010/09/importamce-of -science-and-technology.html

xx. Mosadomi, W. (2014). Analysis of the 2012 November/December NECO examination. Retrieved June 4, 2014 from http://www.vanguardngr.com/2013/03/neco-release

xxi. Njoku, Z. C. (2007). Comparison of students' achievement in the three categories of question in SSCE practical chemistry examination. Journal of Science Teachers Association of Nigeria, 42 (1 & 2), 67-72.

xxii. Oak, M. (2011). Importance of science and technology. Retrieved July 17, 2014 from http://www.buzzle.com/articles/importance-of-science-and-technology.html

xxiii. Okafor, N. P. (2000). Laboratory resources and utilization as correlates of chemistry students' learning outcomes. Proceedings of the 41st Conference of the Science Teachers' Association of Nigeria, 169-173.

xxiv. Olajengbesi, A., & Aluko, K. O. (2000). Effects of concept mapping and problem solving instructional strategies on secondary school learning outcomes in chemistry. African Research Review, 2 (1), 162-176.

xxv. Olorundare, A., & Aderogba, G A. (2009). Comparative effects of concept mapping, analogy and expository strategies on secondary school students' performance in chemistry in Ilesha, Nigeria Journal of Curriculum and Instruction, 7 (1 & 2). Retrieved July 25, 2014 from www.unilorin.edu.ngon

xxvi. Onekutu, P. O. (2002). Gender difference in achievements in junior secondary school examination in integrated science: Implications for national development. In O.O Okpeh (Ed), Review on Gender Studies in Nigeria.

xxvii. Orgil, M., & Bodner, G. (2004). What research tells us about using analogies to teach chemistry. Chemistry Education: Research and Practice, 5 (1), 15-32.

xxviii. Orgil, M. K.,& Thomas, M. (2007). Analogies and the 5E model. Science Teacher, 74 (1), 40-45.

xxix. Sambo, A. A. (2005). Research methods in education. Ibadan: Stirling-Horden Publishing co.

xxx. Schmitz, S., & Grunau, E. (2009). Concept mapping from a perspective of gendered diversity. Paper presented at the 5th European Symposium on Gender and ICT, Bremen.

xxxi. Shuaibu, A. A. M., & Mari, J. S (1997). Gender related difference in the understanding of science process skills amongst junior secondary school students in some Nigerian schools. Journal of Science Teachers Association of Nigeria, 32 (1 and 2), 21-27.

xxxii. Uzuntiryaki, E., & Gedan, O. (2005). Effect of conceptual change approach accompanied with concept mapping on understanding of solution concepts. Instructional Science, 33 (4), 311-339.

xxxiii. Wagner, E. P. (2001). A study comparing the efficacy of a mole ratio flow chart to dimensional analysis for teaching reaction stoichiometry. School Science and Mathematics, 101 (1), 10-22.

xxxiv. West Africa Examination Council. (1995-2012). Chief Examiners' Reports Nigeria. Lagos: Megavons (W.A) Ltd.

Appendix A

The Chemistry Problem Solving Test

1. Q1. Calculate the mass of aluminium that would be deposited during the electrolysis of a molten aluminium salt by a current of 10A flowing for 6 hours 45 minutes. (Al 27, 1F= 96500C)

→ Solution:

The equation for the discharge of Aluminium during electrolysis is:

$Al^{3+}_{(aq)}$ + 3e → $Al_{(s)}$

From this,

1 mole of Al^{3+} is discharged by 3 moles of electrons.

But 1 mole of electrons is equal to 1 Faraday (96500C),

Therefore,

1 mole (27g) of Aluminium is deposited by 3F (3 x 96,500C = 289,500C)

27g of Aluminium is deposited by 289500C

But the quantity of electricity passed in this case is given by:

Q = it

Where Q = quantity of electricity in coulombs,

i = current in Amperes (given as 10A)

t = time in seconds (6hrs 45 mins = 405 mins x 60s= 24300s)

Q = 10A x 24300s

Q = 243,000C.

If 27g of Aluminium will be deposited by 289,500C of electricity,

What mass of Aluminium (xg) will be formed by 243,000C of electricity?

Xg x 289,000C = 27g x 243,000C

Xg = 27g x 243,000C / 289,000C

Xg = 22.66g

Mass of Aluminium deposited by a current of 10A flowing for 6 hrs 45 minutes is 22.66g.

2. Q2. Determine the mass of pure iron (II) chloride formed when 3.20g of iron (II) sulphide react completely with excess dilute hydrochloric acid according to the following equation:
   - $FeS_{(s)}$ + $2HCl_{(aq)}$ → $FeCl_{2\,(s)}$ + $H_2S_{(g)}$
   - (Fe = 56, Cl = 35.5, H = 1, S = 32)

→ Solution:

The equation for the reaction is

$FeS_{(s)}$ + $2HCl_{(aq)}$ → $FeCl_{2\,(s)}$ + $H_2S_{(g)}$.

From the equation,

1 mole of $FeCl_2$ is formed when 1 mole of FeS reacts with excess dilute HCl acid.

1 mole of FeS is 88g,

1 mole of $FeCl_2$ is 127g

Therefore,

88g of FeS reacts with excess dilute HCl acid to form 127g of $FeCl_2$

But the mass of FeS provided for reaction is 3.20g.

Therefore,

If 127g of $FeCl_2$ is formed from 88g of FeS,

How many grams of $FeCl_2$ (Xg) will be formed from 3.20g of FeS?

Xg x 88g = 127g x 3.20g

Xg = 127g x 3.20g / 88g

Xg = 406.4/88

Xg = 4.62g

Therefore,

The mass of $FeCl_2$ formed when 3.20g of FeS reacts with excess dilute HCl is 4.62g

3. Q3. What is the number of moles and the mass of Argon gas present in $1.5x10^{23}$ atoms of the gas? (Avogadro number = 6.02×10^{23}, Ar = 40)

→ Solution:

(a). 1 mole of any substance contains the Avogadro number of particles

1 mole of any substance contains 6.02×10^{23} particles
1 mole of Argon gas contains 6.02×10^{23} atoms
This means that 1 mole = 6.02×10^{23} atoms
But the number of atoms of Argon given is 1.53×10^{23} only.
Therefore:
If 6.02×10^{23} atoms of Argon gas contains 1 mole of Argon,
1.5×10^{23} atoms of Argon gas contains X mole of Argon
1.5×10^{23} x 1 mole of Argon = 6.02×10^{23} x X mole of Argon
X mole = 1.5×10^{23} x 1 mole / 6.02×10^{23}
X mole = 0.25 mole

(b) 1 mole of any substance has a mass equal to its molar/atomic mass

1 mole of Argon is 40g
But number of moles of Argon calculated is 0.25 moles.
Therefore,
If 1 mole of Argon = 40g
0.25 mole of Argon =? (Xg)
Xg x 1 mole = 0.25 mole x 40g
Xg = 0.25 mole x 40g / 1
Xg = 10g