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The Efficacy of Concept Mapping Instructional Strategy in Remedying Students' Problem-Solving Difficulties in Stoichiometry

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Abstract

Concept mapping strategy has been found to be effective in science education. However, its comparative effect in remedying male and female students' problem-solving difficulties in stoichiometric tasks has not been documented. The study aimed at finding the role of concept mapping in remedying students' problem-solving difficulties in stoichiometry. The pre-test-post-test-control group design was employed. 60 male and female students were randomly selected, pretested and assigned into control and concept mapping groups. The control group was taught using lecture method, while the experimental group was taught using concept mapping. A Stoichiometric Problem Solving Test (SPST) was developed and used. Analyses of post-test mean scores using t-test ($\alpha = 0.05$) showed that there was a significant difference between the post-test means scores of students taught stoichiometry using concept mapping strategy and those in the control. No significant difference between the post-test means scores of male and female students taught using concept mapping strategy was found. The efficacy of concept mapping strategy in enhancing students' problem solving ability in stoichiometry among male and female students was therefore established. The study recommended the use of concept mapping strategy by chemistry teachers to teach stoichiometry to improve problem solving among male and female students.

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). The third world countries need this most hence the efforts by many of them to embrace science and technology. Technology is the primary vehicle through which humanity progresses and it will serve 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). Of the science subjects, chemistry stands out as the subject upon which the bulk of the present technological break-through is built (Gongden, 1998). It is an important subject which is seen as hope for individuals and the society.

One of the major domains of research in chemical education is the area of learning (de Jong, Schmidt, Burger & Eybe, 1999). This area is concerned with how chemistry is learned, students' conceptions, their ways of solving problems and their difficulties with the abstract mode of thinking in chemistry. The difficulty in learning chemistry has been established by a number of research works (Gongden, 1998; Ezeudu, 2000; Jimoh, 2004 & Njoku, 2007)). Similarly, other research works have established students' poor performance in chemistry problem solving tasks (Crippen, Brooks, & Courtright, 2000; Wagner, 2001; Danjuma, 2005). These researches along with WAEC chief examiners' reports (1995, 1999, 2000, 2003, 2005, 2007) revealed the chemistry concepts (mostly physical chemistry) with which students experience difficulty in solving chemical problems and which contribute to students' failures in examinations.

The learning of scientific concepts in the Nigeria Senior Secondary School is generally regarded as being difficult for most of the students (Oloyede, 1998). This is particularly true of chemical concepts which are inherently formal in context. The West African Examination Council chief examiners' reports have over the years pointed out the fact that chemistry students often encountered difficulty solving chemical problems tasks. WAEC chief examiners' report 2000 reported that students showed non – familiarity with the use of Avogadro number (constant) in calculations and demonstrated poor mathematical skills. In the 2005 report, students' inability to calculate mole, mole ratio and the use of wrong expressions in solving problems were reported. Commenting on questions involving problem solving in electrolysis, the chief examiners' reports for 1999 and 2003 said that students showed shallow understanding of the concept of electrolysis along with chemical equilibrium and rates of reactions. The general inability of students to tackle most of the numerical (problem solving) questions was also reported. This poor problem solving ability has led to the poor performance of chemistry students in the WAEC examinations (Jimoh 2004; Njoku 2007) with a general decline in performance from 2007 to 2009 (WAEC, 2010). The poor problem solving ability points to a likely deficiency in method of instruction.

Reaction stoichiometric calculations have been difficult for students (Wagner, 2001). This is hinged on the mathematical and practical nature of the subject. Reports showing the central importance of mathematical and problem-solving abilities in students' achievement in chemistry are variously available (Ochonogor 1998). Atkins (1992) noted that mathematics is the biggest difficulty for students beginning their study of physical chemistry and pointed that a mathematical background is therefore very important. Topics involving calculation of volumes and the mole concept have been identified as difficult topics in the S.S.C.E curriculum (Danjuma, 1992). Students' inability to solve quantitative problems in chemistry has continued to attract attention among chemical educators. The concern stems from the fact that chemist function best in problem situation, yet students continue to demonstrate a great resistance to using & interpreting mathematics language in chemistry (Quilze-Pardo & Solaz-Portoles, 1995). Closely related to this is the emphasis that teacher's make of the application of algorithm to so solve quantitative problems. This use of algorithm is insufficient to improve students' problem solving capability. Lee, Goh, Chia and Chin, (1996) believe that training of linkage and problem translation skills is necessary to make learning of problem, solving more meaningful and successful. This is in addition to teaching the prior knowledge needed for solving problems.

Generally, the failure of students to perform well is chemistry is linked to the instructional strategies employed by teachers. One of such methods that has been found effective in science education instruction is the use of concept maps. Concept mapping has been introduced and used in chemistry education to tackle the problem of linking the often multi-dimensional nature of the subject (Fechner & Sumfleth, 2008). The construction of concept maps is a good way of organizing information about a concept. A concept map is a diagram showing relationships among concepts. They are graphical tools for organizing and representing knowledge. It is a way of representing relations between ideas, images or words, in the same way that a sentence diagram represents the grammar of a sentence. Concept maps provide an excellent tool for students to generate meaningful connections between chemical concepts and they provide information about students' conceptual understanding, (Francisco, Nakhleh, Nurrenbern & Miller 2002; Cardellini, 2004).

Statement of the Problem

The poor performance of chemistry students in problem solving has been established by a number of researches amongst which are Cripen, Brooks & Courtright (2000); Wagner (2001) and Danjuma (2005). Some of the concepts that present such difficulty to students include electrochemistry, chemical equilibrium, redox reactions, mole concept and stoichiometry. 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 such as concept mapping, mathematical problem-solving, wait - time, collaborative learning strategies have emerged through researches and have proved effective for learning chemistry and science in general (Gabel, 2003b). Despite the effectiveness of these strategies, the effect concept mapping on male and female problem solving ability in tasks involving the stoichiometry has not been documented especially in Secondary Schools in Plateau state. It is against this background that the study sets out to find out the efficacy of concept mapping on male and female students' abilities in problem solving in stoichiometry.

Purpose of the Study

The main purpose of this study was to find out the effects of concept mapping on students' problem solving ability in stoichiometry. Specifically, the study set to:

i. Find out if the pre-test mean scores of students in concept mapping class differ from the control in a stoichiometric problem solving test.

ii. Find out if the post-test mean scores of students in concept mapping class differ from the control in in a stoichiometric problem solving test.

iii. Find out if the mean score of male students differ from that of the female students in a stoichiometric problem solving test when taught using concept mapping.

Research Questions

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 pre-test mean scores of students in the concept mapping class and the control class in a stoichiometric problem solving test?

ii. What is the difference between the post-test mean scores of students in the concept mapping class and the control class in a stoichiometric problem solving test?

iii. What is the difference between the post-test mean scores of male and female students in a stoichiometric problem solving test when taught stoichiometry using concept mapping instructional strategy?

Research Hypotheses

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

i. There is no significant difference between the pre-test mean score of students in the concept mapping class and those in the control class in a stoichiometric problem solving test.
ii. There is no significant difference between the post-test mean score of students in the concept mapping class and those in the control class in a stoichiometric problem solving test.
iii. There is no significant difference between the post-test mean score of male and female students in a stoichiometric problem solving test when taught using concept mapping strategy.

Methodology

The study was a pre-test-post-test-control group design. The initial behaviour of the groups was determined through a pre-test and was determined again after treatment through a post-test. The pre-test and post-test 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.

Sixty senior chemistry two chemistry students (made up of thirty male and female students each) were randomly sampled from two schools in Jos North Local Government Area of Plateau state - Nigeria. Characteristics common to the population include their use of the same curriculum/syllabus, their being prepared for the same external examinations (WASSCE and NECO), their being from different socio-economic, cultural backgrounds and religious backgrounds and a common way of evaluation. The students were pretested and randomly assigned into control and experimental (concept mapping) groups.

The instrument used to collect data was a stoichiometric problem solving test (SPST). This is necessary because chemistry functions best at problem solving (Danjuma, 2005). The SPST is made up of three questions as follows:

a. Calculate the volume of hydrogen produced at stp when 25g of zinc reacts with excess hydrochloric acid according to the equation:
   $Zn_{(s)} + 2HCl_{(aq)} \rightarrow 2ZnCl_{2(aq)} + H_{2(g)}$

b. What is the mass of iron (II) sulphide formed from the reaction of 28g of iron and 12g of sulphur as represented by the equation?

   $Fe_{(s)} + S_{(s)} \rightarrow FeS_{(s)}$

c. Determine the volume of oxygen used in forming $11.50dm^3$ of sulphur (VI) oxide according to the equation:

   $2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$

(Zn = 65; S = 32; Cl = 35.5; Fe = 56; O = 16, Molar volume of gas at stp = $22.4dm^3$)

The reliability of the CPST was determined using the inter-scorer method (Danjuma, 2005) for determining the reliability of an essay test and the reliability coefficient found to be 0.84. The validity was also established appropriately.

The students were pretested using the SPST after which they were taught the chemistry concept (stoichiometry) spanning over a period of over one week in the control and concept mapping classes. A minimum of three concept maps were used to teach the concept in the experimental class. Students in the control group were not exposed to concept maps but taught using the conventional lecture method. A post-test was administered to each class at the end of the instruction. The t-test for independent sample was used to analyse the data thereby answering the research questions and testing the hypotheses.

Results

The pre-test mean scores of the male and female students were analysed and the results used to answer research question one and to test hypothesis one as follows:

Research question one: What is the difference between the pre-test mean scores of students in the concept mapping class and those in the control group in a stoichiometric problem solving test?

The results as presented in tables 1a and 1b show that the pre-test mean score of the students in the control was 27.63 while that of the concept mapping class was 27.10. The mean difference between the two was 0.53, a negligible figure.

Hypothesis one: There is no significant difference between the pre-test mean score of students in the concept mapping class and those in the control class in a stoichiometric problem solving test.

The p-significant value was found to be 0.675 ($p > 0.05$). This means that there was no statistically significant difference between the pre-test means score of students in the concept mapping class and students in the control group in a SPST. Therefore, the null hypothesis one was accepted (Tables 1a and b).

Table 1a: Group Statistics of Pretest Mean scores of Control and Concept Mapping Groups

Test Group	N	Mean	Stand. Dev	Standard Error Mean
Control	30	27.63	1.786	0.258
Con. Map	30	27.10	2.080	0.300

Table 1b: Independent Sample Test for Equality of Pretest Means of Control and Concept Mapping Groups in SPST

	Mean Diff	t	df	S.E Diff.	P-sig (2-tailed)
Control and Conc. Map	0.53	0.421	58	0.396	0.675

Where df = degree of freedom

Post-test Results

The researcher analysed the post-test scores of the students and presented it appropriately.

Research question Two: What is the difference between the post-test mean scores of students in the concept mapping class and the control class in a stoichiometric problem solving test?

The results analysed and presented in tables 2a and 2b showed that the post-test mean scores of the concept mapping class and the control are not the same. While the concept mapping group had a mean score of 66.00, the control group had a mean score of 59.40. The mean difference was 6.60, the mean scores of concept mapping group being higher than females'.

Research hypothesis Two: There is no significant difference between the post-test mean score of students in the concept mapping class and those in the control class in a stoichiometric problem solving test.

The p-value, 0.017 < 0.05 as presented in table 2b. This showed that the mean score of concept mapping group in a SPST differed significantly from that of the control group. The null hypothesis was rejected and the alternate hypothesis accepted. Therefore, there is a significant difference between the post-test mean score of students in the concept mapping class and those in the control class in a stoichiometric problem solving test (See tables 2a and b)

Table 2a and Table 2b

Table 2a: Group Statistics of Posttest Mean Scores of Students in the Concept Mapping Group and Those in Control Class

Group	N	Mean score	Standard error	Mean diff.
Con. Map	30	66.00	0.593	6.60
Control	30	59.40	0.518	

Table 2b: Independent Sample Test for Equality of Means for Concept Mapping and Control Groups in a SPST

	Mean diff.	T	df	S. E diff.	p-sig (2-tailed)
Equal variance assumed	6.60	2.539	58	0.788	0.017

Research question Three: What is the difference between the post-test mean scores of male and female students in a stoichiometric problem solving test when taught stoichiometry using concept mapping instructional strategy?

The post-test mean score of male students in the concept map group was 66.90 while that of the female students in the same concept map group was 65.10. The post-test mean difference was 1.80 (Table 3a). The difference was not much.

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

Group	N	Mean score	Standard error	Mean diff.
Male	15	66.90	0.658	1.80
Female	15	65.10	0.403	

Research hypothesis Three: There is no significant difference between the post-test mean score of male and female students in a stoichiometric problem solving test when taught using concept mapping strategy.

Analysis presented in table 3b show that the post-test mean scores of male students in the concept map group and that of the female students in the same concept map group did not differ significantly. The p-value, 0.472 > 0.05. This indicated that there was no significant difference between the mean scores of male and female students taught stoichiometry using concept mapping instructional strategy. Hypothesis three (null) was therefore retained. Therefore, there was no significant difference between the posttest mean scores of male and female students in a stoichiometry problem solving test when taught using concept mapping instructional strategy.

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

	Mean diff.	t	df	Standard Error diff.	P-sig (2-tailed)
Equal variance assumed	1.80	0.729	28	0.772	0.472

Discussion of Results

There was no statistically significant difference between the pre-test mean scores of the students in the concept mapping and those in the control groups in a stoichiometry problem solving test. This was probably because of the randomization of the sample. The sample was drawn from a student population that had similar if not the same characteristics. The randomization of the groups also ensured that all the groups are equivalent before the treatment (Akuezuilo & Agu, 1993).

Another finding of the research is that there was a significant difference between the post-test means score of students in the concept mapping class and those in the control class in a stoichiometric problem solving test. This means that when students are taught the concept of stoichiometry using concept mapping, they will perform better in problem solving than students who are not exposed to concept mapping. This shows that concept mapping is an effective instructional strategy for teaching stoichiometry. This finding agrees with earlier finding by Olorundare and Aderogba (2009) who 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. The results of the study also agreed with Gabel's (2003b), Foxwel and Menasce (2004) and Uzuntiryaki and Gedan (2005) who found in their separate studies that metacognitive instructional strategies are effective in learning chemistry and science in general. However, the result 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. Their position may hold for chemistry in general but not the three concepts involved in this research. The possible reasons may include the fact that concept mapping instructional strategy is student centred while lecture method (the strategy used in control) is mainly teacher centred which does not allow for students' participation. Concept mapping provides conceptual bridges between students' current knowledge level and new ideas (Muirhead, 2000) and problem solvers are able to link salient ideas. The remarkable efficacy of concept mapping instructional strategy in enhancing students' problem solving ability in stoichiometry was therefore established.

The third finding of this research was that there was no significant difference between the post-test means score of male and female students in a stoichiometric problem solving test when taught using concept mapping strategy. This means that concept mapping strategy enhanced both male and female students' problem solving ability in stoichiometry equally. This means that the use of concept mapping in teaching stoichiometry is not influenced by gender. This may be due to the advantage that concept mapping presents to all students. Concept mapping helped to show relationship between levels and concepts as they are arranged into a meaningful hierarchy

(Olajenbesi & Aluko 2000). Students are helped to focus on the relationships among concepts for long time (Gabel, 2003b), relating them to one another. Furthermore, the use of concept maps produces significantly higher positive attitude towards science (Chemistry) as a school subject causing a significantly better acquisition of science concepts (Uzuntiryaki & Gedan, 2005). This finding agreed with Adesoji and Jimoh's (2007) and Erimosho in Adesoji and Babatunde (2008) who found out variously 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 stoichiometry. The finding did not agree 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). It also contrasts Baker and Leary's (1995) claim that female students had more difficulties than their male counterparts in chemical problem solving. The researchers here disagreed with this claim and believed that the performance of females in chemical problem solving all depends on the instructional strategy with which they are taught.

Conclusion

The study investigated the effects of concept mapping strategy on students' ability to solve stoichiometric problems. The study found out that concept mapping strategy is very effective in teaching students' stoichiometry. It also established that concept mapping instructional strategy is more effective in enhancing problem solving ability in both male and female students in chemistry tasks involving stoichiometry. The claim that a significant difference occurs between male and female students' problem solving ability may not be true as the performance of females in chemical problem solving depends on the instructional strategy with which they are taught.

The study recommended that concept mapping be embraced and used by chemistry teachers to teach concepts such as stoichiometry in order to improve problem solving among male and female students. The strategy should be employed by teachers in mixed gender and ability classes seeing that it is effective for both male and female students.

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