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Enhancing Pre-Degree Chemistry Students' Conceptual Understanding of Rates of Chemical Reactions through Cooperative Learning Strategy

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Abstract:
This study investigated the effect of cooperative learning strategy on pre-degree students' conceptual understanding of the rate of chemical reactions compared to traditional instruction. A control group and an experimental group were randomly selected from the Remedial Science Department of the University of Jos, Nigeria. The design was quasi-experimental study. A Chemistry Achievement Test (CAT) was administered to students and a sample of one hundred randomly selected from the number that scored forty percent and above. The hundred students were randomly assigned into control and experimental group. The two groups were taught the topic 'rate of chemical reactions' by the same teacher. The control group was taught using the traditional lecture method. The experimental group was taught using cooperative learning strategy. Both instructions lasted two weeks after which the students were administered a post-test called Rate of Reaction Conceptual Understanding Test (RRCUT). The data collected were analyzed by using the independent samples t-test at 0.05 level of significance. The results showed a significant difference in conceptual understanding between the experimental group and the control group in favor of the experimental (cooperative learning) group ($p<0.05$). It also indicated that male students benefitted from the cooperative learning strategy than female students. Therefore, gender has an effect on students' conceptual understanding of rate of reactions when taught in a cooperative learning environment. The study recommended the use of cooperative learning strategy in chemistry classes so as to ease learning difficulties so as to pave way to conceptual understanding of rate of chemical reactions because the strategy allows discussion and critical thinking. Teachers are to be encouraged to use the strategy through workshops, conferences, refresher courses and retreats.

Keywords: *Reaction rate, cooperative learning, conceptual understanding, gender*

1. Introduction

One of the main objectives of science instruction in schools is the enhancement of conceptual understanding (Gabel, 2003b). This is the ability to explain a concept taught in one's own words or ways, having understood it well. Science educators have come to realize that teaching science as a list of facts to be memorized rather than understood is a futile exercise. Focus of research in science education has since shifted from teacher-centered to student-centered and on factors in students' minds such as prior knowledge, misconceptions, memory capacity and cognitive styles (Gongden, 2015). This is as a result of the need to improve students' conceptual understanding, hence the documentation of a variety of labels to describe students' understanding of science concepts.

The difficulty in learning chemistry has been established by a number of research works (Gongden, 1998; Ezeudu, 2000). The subject has been described as a difficult subject for secondary school students to learn (Taber & Coll, 2002). Lack of conceptual understanding has been identified as one of the major reasons for students' dismal performance (Ezeudu, 2000; Ozkaya, 2002). Gabel (2003a) reported that one of the reasons students are unable to solve problems is their lack of understanding of the concepts on which the problems are based. Some of the concepts that present such difficulty to students include rates of reactions, (Taber & Coll, 2002; Sirhan, 2007), electrochemistry, chemical equilibrium, redox reactions, mole concept and stoichiometry (Cripen, Brooks & Courtright, 2000). Other research works have established students' poor performance in chemistry problem solving tasks (Crippen, Brooks, & Courtright, 2000). Kaya (2011) noted that the conceptual understanding of science concepts and their attitudes towards science in general, may differ based on their gender. Some researches show that gender difference has an effect on students' conceptual change

(Cetin, Kaya and Geban, 2009). However, some other researches show that gender difference has no effect on students' conceptual understanding (Cakir, Uzuntiryaki & Geban, 2002; Baser &Geban, 2007). Many studies have reported that male students have a more positive attitude towards chemistry than females (Jones, Howe & Rua, 2000). A few studies however found that female students had more positive attitude towards chemistry than male students (Dhindsa & Chung, 1999).

Teachers play a great role in how students understand and learn the concepts taught in class. Studies show that teachers reflect their already-existing conceptual constructs and their problem-solving processes on students (Kolomuç and Tekin, 2011). They do so through the teaching strategies employed. Gabel (2003a) noted that teachers do not present the concepts in a variety of contexts for students to understand but in verbal and formal ways. This view and other reports 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, concept mapping, mathematical problem-solving, wait - time, collaborative (cooperative) learning, inquiry and learning cycle approach. These strategies are based on the theory of constructivism. The constructivist learning theory argues that individuals generate knowledge and meaning by interacting with the environment. This theoretical framework holds that learning always builds upon knowledge that a student already knows. The constructivist's view of learning is developed based on Kelly's work in the 1950s on personal construct and Ausubel (1968) on learning based on what the learner knows. They found out that knowledge is constructed in the learner's mind through their interaction with the environment. The role of the teacher in a science classroom is to prompt and facilitate discussion (Taber, 2006). The objectives of chemistry education in schools cover the fundamental concepts of chemistry that students should comprehend and the chemical processes that lie behind every day phenomena. It is suggested that school education should enable students to understand their life. This opportunity is presented to a student in a cooperative learning environment.

Cooperative learning is a specific kind of collaborative learning. In cooperative learning, students work together in small groups on a structured activity. They are individually accountable for their work, and the work of the group as a whole is also assessed. Cooperative groups work face-to-face and learn to work as a team. According to Sisovic and Bojovic (2000), this method enables active construction of knowledge, as well as the development of various skills. Research and practice in chemistry education have provided evidence of the positive influence of cooperative learning and interactions of peers to the cognition and development of thinking (Farell, Moog, & Spencer, 1999)

Cooperative learning refers to a set of teaching methods that require active participation of both teacher and students. Instead of transmitting the knowledge in its final shape, it gets formed in the process of student-teacher, student-student, and student-teaching content interactions. Cooperative learning in a group enables the exchange of knowledge and ideas among students who may differ in their developmental levels and prior knowledge; it stimulates the motivation of students to participate actively in the process of learning, because it ensures social - cognitive conflicts due to different views, ideas, and personalities. Many research works and practice in chemistry education have provided evidences of the efficacy of cooperative learning and interactions towards cognition and development of thinking (Farrell, Moog, & Spencer, 1999). Cooperative learning can enable the exchange of knowledge and ideas among students who may differ in their developmental levels and prior knowledge. It also stimulates the motivation of students to participate actively in the process of learning, because it ensures social - cognitive conflicts due to different views, ideas, and personalities. The roles of teacher and students in all forms of cooperative learning are essentially different from those in traditional teaching. The role of the teacher in cooperative learning, as a partner in the interaction, is not limited only to the content of teaching, but extends to a background coordinator' who stimulates students' motivation, student-teacher, and student-student interactions. The teacher stimulates students to make statements, to confront and defend their views and ideas. They direct class discussions and creates situations in which each student will feel free to ask and research; in addition, the teacher structures students' thinking by turning their spontaneous sayings into precise statements, confronting them with their own sayings, leading them by adding sub-questions, and stimulating them to generalize, to extract what is essential, by inviting students to check again, and make comments on what has been stated (Sisovic and Bojovic, 2000).Learning therefore becomes more meaningful to students as the teachers shift their paradigm from replicable knowledge to the construction of individual knowledge which leads to conceptual understanding (Rahmawati, 2008).

2. Statement of Problem

Researchers have pointed out that most chemistry concepts are difficult to grasp. Among the difficult concepts is rate of reactions (also known as chemical kinetics). Studies have indicated that students have many alternative conceptions and face great difficulties in understanding chemical kinetics (Cakmakc¸ 2005, Kousathana and Tsaparlis, 2002). One of the reasons often associated with difficulty of rate of reactions and other chemistry concepts is that the concepts are abstract in nature and require students to construct mental images of things they cannot see (Taber & Coll, 2002; Sirhan, 2007)). Another reason is that a chemical phenomenon requires understanding at both macroscopic and microscopic level. The interactions and distinctions between the levels are important necessary for comprehending chemical concepts (Sirhan, 2007). These reasons account for the difficulty and misconceptions that studentsat all levels of educationhave in chemistry **as** documented by Ben-Zwi et al, 1986; Özmen et al., 2009).

Various studies have been carried out with focus on the difficulties that students have in learning and understanding rates of chemical reactions amongst which are Çakmakçı, Leach & Donnely (2006), Taştan Kırık, and Yalçınkaya& Boz (2010). Chemical kinetics is reported to be difficult for university students to comprehend; mostly because at this level it generally involves more complex mathematics as well as qualitative explanations for both rate equations and variables that affect the rate of a reaction.

Several ways of overcoming some of the difficulties have been suggested to include conceptual change, use of laboratory activities, analogy-assisted change texts, use of basic materials and the use of package software for computer assisted teaching. However, researches have shown that many students still fail to grasp that reaction yield and reaction rate are different concepts (Balcı, 2006). Aydin et al. (2009) and WAEC (2012) also reported that most students at all levels still have problems in discriminating the reaction rate and the extent of reaction. There has been very little research about the students' conceptual understanding of rates of chemical reactions especially in Pre-degree (Remedial) Science class. Furthermore, the comparative effects of cooperative learning strategy on male and female students' conceptual understanding of rates of chemical reactions have not been documented.

3. Objective of the Study

The purpose of this study is to investigate the effect of cooperative learning strategy on pre-degree students' conceptual understanding of the rate of chemical reactions. Specifically, it compared the effectiveness of cooperative learning to traditional instruction in terms of students' conceptual understanding of rates of chemical reactions. The study also aimed at finding out if the conceptual understanding of the male and female students differs significantly in the experimental (cooperative) group. The pertinent questions are:

i. Will cooperative learning strategy enhance pre-degree students' conceptual understanding of rate of reactions?
ii. Will there be any significance difference in the performance of male and female students taught in a cooperative learning strategy in a conceptual understanding test involving rate of reaction?

4. Hypotheses

The following null hypotheses were tested at 0.05 level of significance.

i. There is no significant difference in the mean scores of the students taught rates of chemical reactions using cooperative learning strategy and those in the control.
ii. There is no significant difference in the mean scores of male and female students taught rates of chemical reactions using cooperative learning strategy.

5. Materials and Methods

The quasi-experimental design was used in this study. The study was conducted in the Remedial Science Department of the University of Jos, Nigeria. The chemistry students were administered a chemistry achievement test, CAT with a view to ascertaining their background knowledge in chemistry. The CAT was a 40-item multiple choice test with four alternative responses A-D among which only one was correct. The questions were drawn from past Senior School Certificate Examination. Whatever a student scored was considered a fair assessment of their background knowledge in chemistry. The pass mark was set at forty percent. From the number that passed, a sample of fifty males and fifty female students was randomly selected. The students were randomly assigned into control and experimental group. In each group, there were twenty-five male and female students each. Each teaching approach used in the study was randomly assigned to each group.

In the experimental group, students were taught using collaborative/cooperative strategy in groups of seven. Two cooperative learning forms are used: students working in groups, and a teacher-student form. The teacher started the instruction with a class presentation. He presented the concepts and necessary information that would be used by the students during their group activities after the presentation. Teacher presentation sessions took about one hour depending on the topic for each week. After the teacher presentation, group members came together to study worksheets. The worksheets demanded group members to discuss among themselves in order to reach a common solution instead of loading the responsibility onto one or two students. These questions also included those requiring interpretations of events from daily life (analogies) related to reaction rate. They worked in the same groups to perform experiments, discuss questions and draw conclusions. While they collaborated and discussed, the teacher walked around, answering any questions where necessary in their groups.

In the control group, the students were taught by the traditional lecture (teacher-centered) approach. The students listened to the teacher's lecture and took notes. After the teacher's explanations, he asked questions and students responded to the best of their ability where possible. The students also asked questions where necessary.

Both groups were taught by a chemistry teacher with over fifteen years of teaching experience for two weeks of six chemistry hours. Topics covered include: meaning of reaction rate, ways of measuring reaction rates, how reaction rates vary, the collision theory and factors affecting rates of chemical reactions (concentration, temperature, catalyst, light, surface area, nature of reactants). At the end of the period, the students were administered a Rate of Reaction Conceptual Understanding Test (RRCUT) which required the students to answer in their own words so as to express their understanding of the concept. There were three questions in all. The test covered rate of reaction concepts including reaction rate, collision theory, activation energy, and the factors affecting reaction rate (concentration, temperature, surface area, and catalyst).

The questions in the RRCUT were:

1. Explain in your own words whatyou understand by the term "rate of reaction".
2. How does the rate of reaction change with time from the beginning until the end of the reaction? Explain as much as you can.
3. What do you understand by the term "activation energy"? Explain in your own words.
4. Consider the reaction represented by the equation:
   $A + B \rightarrow C \ \Delta H = +ve$
   What will be the effect of increase in temperature on the reaction rate? Explain to the best of your understanding.

The validity and reliability of the CAT and RRCUT were all established through pilot testing and Pearson Product-Moment Coefficient (PPMC). The Pearson Product-Moment Coefficient of the CAT and RRCUT were found to be 0.82 and 0.88 respectively. The data obtained from the RRCUT was analyzed appropriately.

6. Results

The data obtained from the RRCUT were analyzed using t-test and compared at 0.05 level of significance. The results were presented appropriately and used to test the null hypotheses.

Group	N	Mean	Standard Deviation	Stand. Error Mean
Control	50	54.74	5.731	0.831
Experimental	50	61.48	7.307	1.033

Table 1a: Group Statistics (t-test) For Mean Performance of Experimental and Control Group in RRCUT

Mean Diff		t	df	S.E Diff.	P-Sig (2-tailed)
Equal Variance Assumed	-6.74	-5.132	98	1.313	0.000
Equal Variance Not Assumed	-6.74	-5.132	92.74	1.313	0.000

Table 1b: Independent Sample Test for Equality of Means (Experimental and Control Groups)

The mean score of the students in the control group (54.74) differed from the mean score of students in the experimental (cooperative) group (61.48) by 6.74 in the RRCUT. This is shown in table 1a. The students in the cooperative group benefitted from the instruction and performed better in the rate of reaction conceptual understanding test than those in the control group.

6.1. Hypothesis One

There is no significant difference in the mean scores of the students taught rates of chemical reactions using cooperative learning strategy and those in the control.

Table 1b showed that p-sig is 0.000 (<0.05). This means that there is a significant difference in the mean scores of the students taught rates of chemical reactions using cooperative learning strategy and those in the control. The null hypothesis was not retained. Therefore, there is a significant difference in the mean scores of the students taught rates of chemical reactions using cooperative learning strategy and those in the control.

Sex	N	Mean	Standard Deviation	Stand. Error Mean
Male	25	60.90	7.88	1.114
Female	25	55.32	5.608	0.793

Table 2a: Group Statistics (t-test) For Mean Performance of Male and Female Students in Experimental Group in RRCUT

	Mean Diff	t	df	S.E Diff.	P-Sig (2-tailed)
Equal Variance Assumed	5.58	4.08	48	1.3677	0.000
Equal Variance Not Assumed	5.58	4.08	44.25	1.3677	0.000

Table 2b: Independent Sample Test for Equality of Means (Male and Female Students in Experimental Group) in RRCUT

The results in table 2a showed that the mean score of the male students in the cooperative learning (experimental) group was 60.90 while that of the female students in the same group was 55.32. Table 2a showed that the mean difference was 5.58. This means that the male students benefitted more from the cooperative learning strategy than the female students in same group.

6.2. Hypothesis Two

There is no significant difference in the mean scores of male and female students taught rates of chemical reactions using cooperative learning strategy.

From the analysis presented in table 2b, p-sig was found to be 0.000, a value less than 0.05. This means that there is a significant difference in the mean scores of male and female students taught rates of chemical reactions using cooperative learning strategy. The null hypothesis two was rejected in favor of the alternate that there is a significant difference in the mean scores of male and female students taught rates of chemical reactions using cooperative learning strategy.

7. Discussion

The study investigated the effects of cooperative learning on pre-degree chemistry students' conceptual understanding of rate of chemical reaction. According to the results, the cooperative learning group resulted in a significantly better conceptual understanding and acquisition of knowledge related to reaction rate than traditional group (control). The pre-degree students taught rate of reaction in a cooperative class scored higher in a conceptual understanding test than students taught using the conventional lecture method. The effectiveness of cooperative learning on students 'conceptual understanding derived its support from previous studies such as Acar and Tarhan, 2007 and Doymus- Koç, Doymu & Karaçöp & Simsek (2010). Koç, Doymus, Karaçöp& Simsek (2010) studied the effects of two cooperative learning strategies on the teaching and learning of chemical kinetics and concluded that the teaching of chemical kinetics via the jigsaw and group investigation techniques was more effective in increasing academic achievement compared to the traditional teaching method. The finding is also in agreement with other studies in the science literature using cooperative learning strategy (Mestre & Cocking, 2002). The students in the cooperative class performed better than those in the control because cooperative learning strategy allows discussion and critical thinking thereby enabling students to learn more and remember what they've learned for a longer period of time. Cooperative learning has shown to be an effective student-centered pedagogical approach that promotes positive student learning outcomes (Kirik and Boz, 2012).

The study also found that there was a statistically significant difference in the mean scores of male and female students taught rates of chemical reactions using cooperative learning strategy. In this study, the male chemistry students benefitted more from cooperative learning strategy than female students in a RRCUT. It should be noted that no study has been carried out on the effect of cooperative learning strategy on gender and chemistry students' conceptual understanding of rate of reaction hence there was no result to compare with. However, several studies have presented results that showed significant differences between male and female chemistry students such as Adesoji & Babatunde (2008), and Dhindsa & Emran (2011).These reported male dominances over female chemistry students. Shuaibu & Mari (1997) and Armagan, Sagir and Celik (2009) in their separate studies reported female dominance especially in chemistry problem solving tasks. This finding however, disagreed with Kaya's (2011) result. In a study on the effect of conceptual change based instruction on students' understanding of rate of reaction concepts, Kaya (2011) found out that there was no significant mean difference between the post-test mean scores of females and males with respect to their attitude towards chemistry as a school subject. Similarly, no significant difference was found to exist between the post-test mean scores of male and female students with respect to understanding of concepts on one hand (and achievement on the other) in rate of reactions concepts when science process skill is controlled as a covariate. It also disagreed with Baser & Gedan (2007) and Cakir, Uzuntiryaki & Geban (2002) who reported that gender difference did not affect conceptual understanding of chemistry students. The effect of gender on students' conceptual understanding in a cooperative learning group may be attributed to the differences in the prior experience of the male and female students with which they bring to bear in class. Male students are more field-independent learners and therefore used active reasoning patterns including cognitive structuring skills than females during discussions. Female students so much subscribe to local customs and values that sometimes keep them away or restrain them from exposure or participation in discussion as in a cooperative group.

8. Conclusion

Rate of chemical reactions is a very important pre-requisite for understanding other chemical concepts such as chemical equilibrium, yet students often have misconceptions about it. This often leads to difficulty in learning other chemical concepts. The findings of the study indicated that cooperative (or collaborative) learning strategy enhanced students' conceptual understanding of the rate of reaction than the traditional teaching. It also indicated that male students benefitted from the cooperative learning strategy than female students. Therefore, gender has an effect on students' conceptual understanding of rate of reactions when taught in a cooperative learning environment. The findings of the study provide further evidence that the student - centered approaches are more effective in enhancing conceptual understanding of chemistry concepts than teacher – centered strategies. Based on the result of the study, cooperative learning seems to be a reasonable method or strategy to teach rate of chemical reactions and improve students' conceptual understanding of the concept.

The study recommended the use of cooperative learning strategy in chemistry classes so as to ease learning difficulties so as to pave way to conceptual understanding of rate of chemical reactions because the strategy allows discussion and critical thinking. Students learn more and remember what they've learned for a longer period of time. Teachers should be encouraged to use the strategy through workshops, refresher courses, retreats, etc. To make the strategy most effective, teachers should group the students heterogeneously and discourage competitions and dominance of discussions by the outspoken.

9. References

i. Acar, B. & Tarhan, L. (2007). Effect of cooperative learning strategies on students' understanding of concepts in electrolysis. International Journal of Science and Mathematics Education, 5 (2), 349-373
ii. 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
iii. Ausubel, D. P. (1968). Educational psychology: A cognitive view. New York: Holt Rhinehart and Winston.
iv. Aydin, S., Aydemir, N., Boz, Y., Cetin-Dindar, A. & Bektas, O. (2009). The contribution of constructivist instruction accompanied by concept mapping in enhancing pre-service chemistry teachers' conceptual understanding of chemistry in the laboratory course. Journal of Science Education and Technology, 18 (6), 518 - 534
v. Balcı, C. (2006). Conceptual change text oriented instruction to facilitate conceptual change in rate of reaction concepts. Unpublished Master Thesis, METU, Turkey.
vi. Baser, M. & Gedan, O. (2007). Effectiveness of conceptual change instruction on understanding of heat temperature concepts. Research in Science and Technological Education, 25 (1), 115-133.

vii. Ben-Zwi, R., Eylon, B. & Silberstein, J. (1986). Is an atom of copper malleable? Journal of Chemical Education. 63, 64-66

viii. Cakir, O. S., Uzuntiryaki, E. & Geban, O. (2002). Contribution of conceptual change texts and concept mapping to students' understanding of acids and bases. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA.108

ix. Cakmakci, G. (2005). A cross - sectional study of the understanding of chemical kinetics among Turkish secondary and undergraduate students. Unpublished doctoral dissertation. The University of Leeds, UK.

x. Çakmakçı, G., Leach, J. & Donnelly, J. (2006). Students' ideas about reaction rate and its relationship with concentration or pressure. International Journal of Science Education, 28(15), 1795–1815.

xi. Cetin, P. S., Kaya, E. & Geban, O. (2009). Facilitating conceptual change in gases concepts. Journal of Science Education and Technology, 18 (2), 130 - 137.

xii. Dhindsa, H. S. & Chung, G. (1999). Motivation, anxiety, enjoyment and values associated with chemistry learning among form 5 Bruneian students. Paper presented at the MERA-ERA joint conference, Malacca, Malaysia.

xiii. Dhindsa, H. S. & Emran, S. (2011). Using interactive whiteboard technology-rich constructivist learning environment to minimize gender differences in chemistry achievement. International Journal of Environmental and Science Education, 6 (4), 393-414.

xiv. Ezeudu, F. O. (2000). The use of local material in the teaching of chemistry. Proceedings of the41st Conference of the Science Teachers' Association of Nigeria, 163-165.

xv. Farrell, J.J., Moog, R. S., & Spencer, J.N. (1999). A guided-inquiry general chemistry course, Journal of Chemical Education. 76 (4), 570

xvi. 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

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

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

xix. Gongden, E.J. (2015). Comparative effects of two metacognitive instructional strategies on gender and students'problem-solving abilities in selected chemistry concepts. Unpublished doctoral thesis, Abubakar Tafawa Balewa University, Bauchi

xx. Jones, G. M., Howe, A., & Rua, M. J. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. Science Education, 84 (2) 180 - 192.

xxi. Kaya, E. (2011). The effect of conceptual change based instruction on Students' understanding of rate of reaction concepts. Unpublished doctoral thesis, Middle East Technical University.

xxii. Kirik, O.T & Boz, Y. (2012). Cooperative learning instruction for conceptual change in the concepts of chemical kinetics. Chemistry Education Research and Practice, 13, 221-236

xxiii. Koç , Y., Doymus, K., Karaçöp, A. & Simsek, U. (2010). The effects of two cooperative learning strategies on the teaching and learning of the topics of chemical kinetics. Journal of Turkish Science Education (TUSED). 7 (2), 52 - 65

xxiv. Kolomuç, A. & Tekin, S. (2011). Chemistry teachers' misconceptions concerning concept of chemical reaction rate. Eurasian Journal of Physics Chemistry Education, 3 (2), 84-101

xxv. Kousathana, M. & Tsaparlis, G. (2002). Students' errors in solving numerical chemical-equilibrium problems. Chemistry Education Research and Practice. Issue 1 (3), 5 1- 17

xxvi. Mestre, J. P. & Cocking, R. R. (2002). Applying the science of learning to the education of prospective science teachers. In Bybee R. W. (ed). Learning science and the science of learning. Science Educators' Essay Collection. Arlington, VA: National Science Teachers Association Press, Chapter Two

xxvii. Ozkaya, A. R. (2002). Conceptual difficulties experienced by prospective teachers in Electrochemistry : half cell potential and chemical and electrochemical equilibrium in galvanic cells. Journal of Chemical Education,79 (6), 735-738.

xxviii. Özmen, H., Demircioğlu, H. & Demircioğlu, G. (2009). The effects of conceptual change texts accompanied with animations on overcoming 11th grade students'alternative conceptions of chemical bonding. Computers & Education, 52(3), 681-695.

xxix. Rahmawati, Y. (2008). The role of constructivism in teaching and learning chemistry. Retrieved July 20, 2009 from http://www.pendidikansains.wordpress.com/category/kuliah/research- methods/

xxx. 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.

xxxi. Sirhan, G. (2007). Learning difficulties in chemistry: An overview. Journal of Turkish Science Education, 4 (2), 2-20

xxxii. Sisovic, D. & Bojovic, S. (2000). Approaching the concepts of acids and bases by cooperative learning. Research and Practice in Europe. 2 (1), 263 - 275

xxxiii. Taber, K. S. (2006). Beyond constructivism: The progressive research programme into learning Science. Studies in Science Education, 42, 125-184.

xxxiv. Taber, K. S. & Coll, R. K. (2002). Bonding. In Gilbert J. K., De Jong O., Justi R., Treagust D. F., Van Driel J. H. (eds) Chemical education: towards research-based practice. Kluwer, Dordrecht, 213-234

xxxv. Tastan, O., Yalçınkaya, E., & Boz, Y. (2008). Effectiveness of conceptual change text - oriented instruction on students' understanding of energy in chemical reactions. Journal of Science Education and Technology, 17(5), 444 - 453.

xxxvi. Tastan Kırık, O. & Boz, Y. (2010). Effects of cooperative learning on students' understanding of reaction rate. XIV Symposium of the International Organisation for Science and Technology Education (IOSTE), Bled, Slovenia, 13-18 June.

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