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Improving Students' Performance in Stoichiometry through the Implementation of Collaborative Learning

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Abstract: The study was designed to foster the implementation of collaborative learning in stoichiometry among secondary school students. It was hypothesized that students who were exposed to collaborative learning will not perform significantly better than those exposed to lecture method. The design of the study was a pretest – posttest non-equivalent control group design. Two hundred and eighty seven Senior Secondary class 2 students from Special Science Schools in Anambra State, Nigeria participated in the study. The reliability of the instrument, Stoichiometry Achievement Test (SAT) was established using split-half reliability coefficient. Analysis of covariance (ANCOVA) was used to test the null hypothesis after obtaining the mean of the pretest and posttest scores. The results revealed that collaborative learning significantly enhanced students' performance in stoichiometry, as students who were exposed to collaborative learning outperformed those exposed to lecture method. Based on the findings of the study educational practices in Nigeria were urged to promote and implement collaborative learning and decrease on the structure of transmission model.

Keywords: *Collaborative learning, Stoichiometry, Performance*

1. Introduction

Research has shown that Nigerian students persistently perform poorly in chemistry owing to poor problem-solving in stoichiometry (Opara, 2013; Udosoro, 2011; Badru, 2004). West African Examinations Council (WAEC) Chief Examiners, perennially report on students' weaknesses in chemical arithmetic, poor mathematical skills and inability to determine mole ratio from stoichiometric equations (2002 – 2012). The field of stoichiometry involves all forms of measurements and the calculations that relate to each other. Stoichiometry is at the heart of chemistry since it refers to the relationship between the measured quantities in a chemical reaction as well as the calculation which include the assumption of the laws of definite proportions and of the conservation of matter and energy. Stoichiometry requires that the number of atoms or molecules involved in chemical reaction be converted into measured quantities expressible in convenient units. Parker (1983) proposed four groups that constitute the principle of stoichiometry. They are: (i) the law of conservation of matter (ii) the law of chemical combining weights (ii) the law of combining proportions (iii) the rates of reaction relationships in a system. Calculations involving these principles are of great significance in engineering practice and existing operations or designing new manufacturing particles and equipment. A solid foundation in stoichiometry is necessary for understanding quantitative deductions in physical chemistry.

Despite the relevance of stoichiometry in physical chemistry studies have shown that learners find stoichiometric calculations difficult (Evans, Yaron & Leinhardt, 2008; Fach, de Boer & Parchmann, 2007 and Furio, Azconu & Guisasola, 2002). Evidence of students' misconceptions and understanding of stoichiometry exists in literature (Gauchon & Meheut, 2007; Arasasington, Taagepera & Potter 2004). Other researches attempted to develop problem-solving models and instructional strategies to foster students' success in stoichiometry (Chandrasegran, Treagust, Waldrip & Chandrasegaran, 2009). There is a clear relationship between students' proficiency in mathematics and their understanding of chemical arithmetic (Badru, 2004 & Adeboyel, 1999). Krammer (2000) observed that mathematics problem-solving affects students' ability to solve problems in chemistry. Studies have also shown that many students suffer from mathematics anxiety which impacts on their problem-solving skills (Hopko, 2003; Stuart, 2000 and Kelly & Tomhave, 1985). Thus, it is essential to create anxiety-free environment within a social, democratic field where learners can fully participate in the learning process and engage one another's intellectual, academic and social aptitudes.

In the past two decades literature has divulged the growing interest in collaborative learning as an instructional strategy that promotes higher order cognitive skills and achievement gains (Wenzel, 2007; Rogoff, 2003; Cross, 2000), yet its application in Nigerian schools at all levels has been scrubby. Research has shown that instructional procedure in Nigerian school system is heavily driven by teacher-talk and depends on textbooks for structure of the course (Bamidele & Oloyede, 2013; Opara, 2013).In the classroom, teachers serve as main channel of knowledge to transfer their thoughts and lessons to passive students who should regurgitate the accepted procedure with little or no input and critical thinking. Callahan, (1962) referred to this type of learning as the "factory model" because the teacher is seen as the technical worker who is expected to insert information into the learner, the receptor of information. In the factory model the learner does not cooperate or discuss with other learners unless s/he is permitted to do so. Thus, the factory model seldom takes the learner's contribution or ideas in to consideration. The teacher delivers the curriculum, asks questions to which s/he knows the answers. The teacher evaluates the students' ability to participate in the lesson through learners' responses to give right answers as given by the teacher. Studies have shown that in Nigeria teachers persist in using the "factory model" because they do not possess the prerequisite knowledge needed for activity-based learning and therefore cannot apply modern teaching methods (Salman, Olawoye & Yahaya, 2011; Nwosu, 2004). In addition, teachers find it more convenient to use the lecture method in the face of overcrowded classrooms and in a bid to cover many topics as stipulated in their weekly schemes of work. Learning has continued to foster the philosophy of transferring information from the external world to the mind of the learner (Rogoff, Mutusov & White, 1996).

Sociocultural scholars projected learning as a process of transformation through participation in ongoing cultural activities (Rogoff, 2003; Lave & Wenger, 1999). In the view of Bruffee (1984) to think well as individuals we must learn to think well and converse well collectively. Literature on collaborative learning commend the attributes students exhibit through active engagement while working in groups to achieve learning goals (Prince, 2004; Silvermann & Casazza, 2000 & Cross 2000).Collaborative learning is an active learning process in which students working in groups negotiate and construct their own meaning and ideas during the learning process to arrive at common goal. Collaborative learning is a non-foundational pedagogy which is grounded in social constructivism. Proponents of collaborative learning regard knowledge as being socially constructed and reveal classroom authority as shared by students and instructor (Bruffee, 2009). Researches ascribed a number of attributes to collaborative learning. According to Holt (1988) collaborative learning enhances critical thinking in learners. Others assert that collaborative learning enhances the attainment of pedagogical objective and sense of community awareness (Wenzel, 2007, Cross, 2000; Gamson, 1994). During the process of collaborative learning, intellectual negotiation between student-student and or student–teacher enables both instructor and student to attain collective decision-making in open-ended tasks which is either mutually determined or assigned by the teacher. Despite the popularity in literature on the relevance of collaborative learning, evidence of non-practice in Nigerian secondary schools abound. The premise of this study was to implement the application of collaborative learning in the teaching of stoichiometry – an aspect of chemistry which students find difficult.

2. Theoretical Framework

Collaborative learning is grounded on social constructivism. Social constructivism is based on the work of Piaget, Vygotsky, Bartlette, Bruner, Rogoff & Gestalt psychologists who theorized that learners' understanding is both individual and social process (Woolfolk & Margetts, 2013). Social constructivism is entrenched in the theory which attributes social and cultural interactions as the means to which learners construct meaning. Participation in a broad range of activities allows learners to be able to appropriate the outcomes produced by democratically working in groups. Vygotsky believed that learning occurred in two stages: first, within the sociocultural environment and then individually as students process the learning experience and integrate the information into pre-existing mental structures or schemas. Therefore, learning cannot be separated from the social and cultural settings in which it took place. Hence, Rogoff (2003) questioned the transmission mode of learning characterized by the factory model. He proposed that learning is a process of transformation of participation in ongoing cultural activities. Active participation of learners within a group which Sfard (1998) referred to as doing through constant flux contrasts with teacher-centered approaches or lecture method which upholds learning as individual process rather than as groups. However, educational practices in Nigeria has continued to promote the latter with the result that students pass through school without acquiring the competencies needed in the competitive market in addition to frequent failure rate in the sciences especially chemistry.

Statement of Problem: Studies have shown that students' lack of problem-solving skills in stoichiometry has persistently resulted to poor performance in chemistry. Despite, the growing interest in collaborative learning as an instructional strategy which promotes critical thinking and actively engages students in learning process for enhanced intellectual, academic and social growth, evidence of its practice in Nigerian secondary schools is still sparse. Given therefore, the need to foster the implementation of collaborative learning among secondary school students, this study aimed at investigating the extent to which collaborative learning will improve students' performance in stoichiometry.

Research Question: What is the mean performance scores in stoichiometry of students exposed to collaborative learning and those exposed to traditional method.

Hypothesis: The mean performance scores in stoichiometry of students exposed to collaborative learning would not differ significantly from those exposed to traditional method.

3. Methodology

The design of the study is quasi-experimental. Specifically, pre-test, post-test non- equivalent control group design is employed. The fact that intact classes that were non-equivalent were used justified the research design. Population of the study comprised all Girls' Special Science Schools in Anambra State, Nigeria. Purposive sampling was used to draw two-only girls' Special Science schools in the State. Justification for choice of only Special Science Schools stems from the fact that chemistry is a compulsory subject for all students. Also, teachers in the schools qualify for the subjects they teach and overcrowded classrooms are usually discouraged. This gives room for effective collaboration in groups. All students in each of the intact classes participated in the study. The two schools are about 80KM away from each other. Hence, random sampling was used to assign control and experimental groups. The control group comprised 142 subjects while the experimental group comprised 145 subjects. A total of 10 intact classrooms (5 classrooms each for control and experimental groups) were involved in the study.

Instrument for Data Collection: The instrument for the study Stoichiometry Achievement Test (SAT) was a 20-item multiple choice question developed by the researcher based on SS2 curriculum on stoichiometry. The instrument was both face and content validated and trial tested in one of the comprehensive secondary schools in the State. The reliability of the instrument determined using split-half reliability coefficient gave 0.80. The teacher who participated in experimental group was exposed to three weeks training. The lesson plans were given to teachers of the experimental group after the training. The experiment lasted for four weeks and it was based on the mole calculations; chemical equations; interpretations from acid-base reactions and percentage yield.

Instructional Procedure: Two instructional procedures were used for the study. Teachers in the control school used the lecture method of instruction which they were familiar with. Before treatment, SAT was administered to all the students as a pretest. At the end of the treatment, SAT was re-administered as post-test.
Sample Instructional procedure for treatment Group

Phase one: Investigate: Groups (4 per group) exploit resources. You are provided with weighing balances, water, salt samples as labeled, plastic measuring containers, reagents. Different groups of students were given different salt samples.
(i) in your various groups, measure the following quantity out of the salt sample given to you say 1.0gm, 4.0gm, 6.0gm 2.5gm, 5.0 gm and label them A, B, C, D, EW hat is the ratio of A: C; E : B

(ii) In your various groups write the formulae of the salt samples before you. (iii) Using the Periodic Table calculate the molar mass of each salt sample and identify each sample as A, B, C, D, E. Again determine the ratio of A: E; C: B and D: A

Phase two: Create: Add a few drops of Sodium Hydroxide solution from the reagent bottle to a solution of Copper II Sulphate. Record your observation. Write a balanced equation of the reaction. Identify the reactants and products. Write four possible mole ratios for the equation. What is essential for all calculations involving amounts of reactants and products?
(iv) What is mole ratios used for? Convert the masses you measured in (i) above to moles and determine ratio of A: C; E: B (iii) Could you have measured the salt samples on the weighing balance directly in moles?
Phase III Discuss Share your ideas, compare notes.
Phase IV Reflect: Interpret the following and use it to calculate the problems you select (from the text or internet) in your various groups on your worksheets
aZ → bY.

Quantity Given Quantity Wanted
Mass of substance Z x 1 mol Z/massZ →mol Z x b mol Y/a mol Z→mol Y x mass Y→1mol Y→mass of Y
Example 2 Limiting Reagent and Percentage Yield
Specific Objective: By the end of the lesson the students should be able to (i) Calculate the percentage ethanoic acid in vinegar
Phase I-investigate: A student collects the following data for the purpose of calibrating a dropper pipette in the laboratory. The calibration involves determining the volume of a drop of water delivered in the pipette. Review the data and answer the following questions.
Number of Drops and their Volume
Number of drops Corresponding Volume (Cm^3)
12020
60 5
3015
14412
72 6
Which ratio is most useful to the student for calibrating the pipette. What is the percentage ratio of total number of drops to volume?

Phase II - Create: You are provided with the following samples Washing Soda, Vinegar, sodium hydroxide, indicator. Write out the apparatus you would need to titrate a standard solution of 0.1MNaOHagainst vinegar. Pipette 25Cm^3 of 0.1M NaOH. Using methyl orange as indicator, titrate against 50 Cm^3 of vinegar solution. To obtain accurate data from your titration discuss and write down all the precautions you must take. Show how you arrived at the mean of three different titers.
Write a balanced equation for the reaction between Sodium Hydroxide and Ethanoic acid. Convert each quantity of reactants into moles.
Discuss – What is limiting reagent? What happens in a chemical reaction when limiting reagent is used up? What is excess reagent? What is percent yield? How will you determine percent of ethanoic acid in the vinegar? Discuss the factors that may because percent yield to be less than 100 percent. Deduce a formula that could enable you calculate percent yield in a chemical reaction.

4. Results

The figure below shows the Student's score in stoichiometry for Control and Experimental group in both pretest and posttest performance. In general, The experimental group performed better than the control group. In the pretest, the percentage mean score for the control group was 18.6± 1.3 % while that for the experimental group was 20.08 ± 0.9%. In posttest, the mean score for the Control group was 22.08±1.4 % while that for the experimental group was 28.83 ± 1.1 %. The standard error as shown with the error bars (±) indicated that there was signifficant difference in both pretest and post test performance and comparing the control and experimental group.

Figure 1: Percentage Mean score for Mathematics students in both control and experimental group; pretest and posttest scores

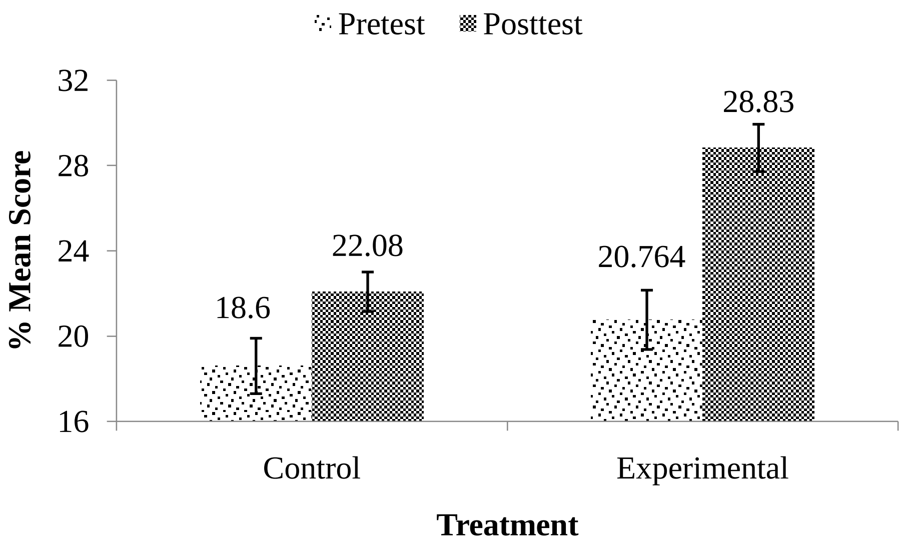
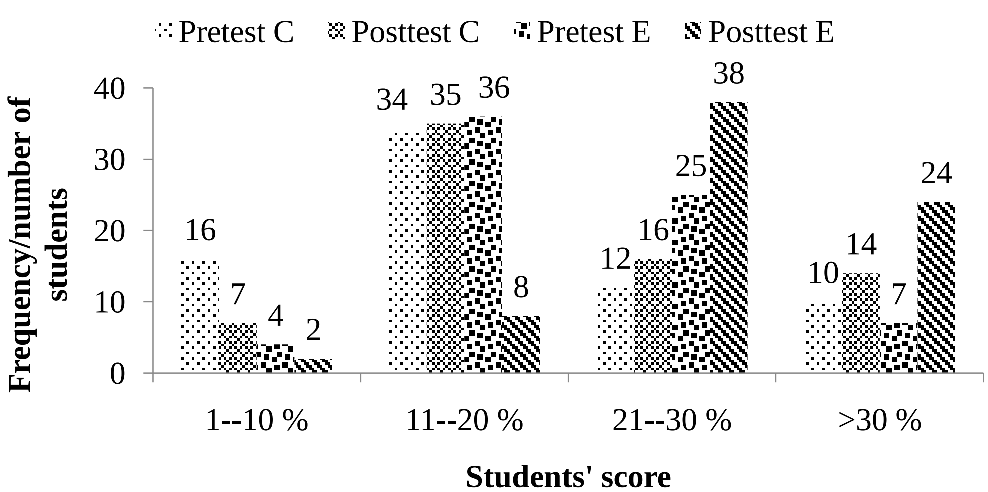


Figure 2 shows the number of students in each percentage class interval 1-10 %, 11-20 %, 20-30 % and > 30%. For the pretest control, most of the students scored between 11-20% (34), 16 students had a score between 1-10%, 12 students ranged between 21-30% and 10 students scored >30 %. For the posttest control, most of the also scored between 11-20 %, however, it was followed by mean score between 21-30% (16 students) then >30% (14 students); 1-10% had the least number of students (7). However, in the experimental group, both pretest and posttest had the lowest number of students in the percentage score between 1-10% 4 and 2 respectively. Most of the students in the pretest performance scored between 11-20% (36) followed by 11-20 % (25) then > 30% (11).The posttest performance was however different in that, most of the students scored between 21-30 % (38) flowed by > 30% then 11-20% (7).



Key Pretest C ≡ pretest control
Posttest C ≡ posttest control
Pretest E ≡ pretest experimental
Posttest E ≡ posttest experimental

Two-way analysis of variance was done on prior log transformed data to test for normality. There was very significant difference with the treatment (control and experimental group) $p < 0.00$ and also with the test group (pretest and posttest) $p < 0.00$. However, there was no interaction effect between the treatment and test $p = 0.18$.

Table 1: Two way analysis of variance for treatment and test effect on students' performance in mathematics

Source	DF	SS	MS	F	P
Treatment	1	0.9583	0.95829	23.1	0
Test	1	0.9742	0.97422	23.5	0
Interaction	1	0.0756	0.07563	1.82	0.18
Error	284	11.794	0.04153		
Total	287	13.802			

The general performance in stoichiometry was as presented in table 2. Most of the students performed better in experimental group than in control group as shown with the means and the range of these means. The performances were also significantly different from each other. The same observation was noted with posttest and pretest in that, posttest performance was better than the pretest performance and they too were also significantly different from each other.

Table 2: 95% confidence limit for the log transformed data on students' score

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 Individual 95% CIs For Mean Based on
 Pooled Standard Deviation
Treatment Mean--------+---------+---------+---------+-
Control 1.24470(------*------)
Experimental1.36007 (------*------)
 --------+---------+---------+---------+-
 1.250 1.300 1.350 1.400

 Individual 95% CIs For Mean Based on
 Pooled StDev
Test Mean--------+---------+---------+---------+-
Posttest1.36054 (------*------)
Pretest 1.24422(------*------)
 --------+---------+---------+---------+-
 1.250 1.300 1.350 1.400
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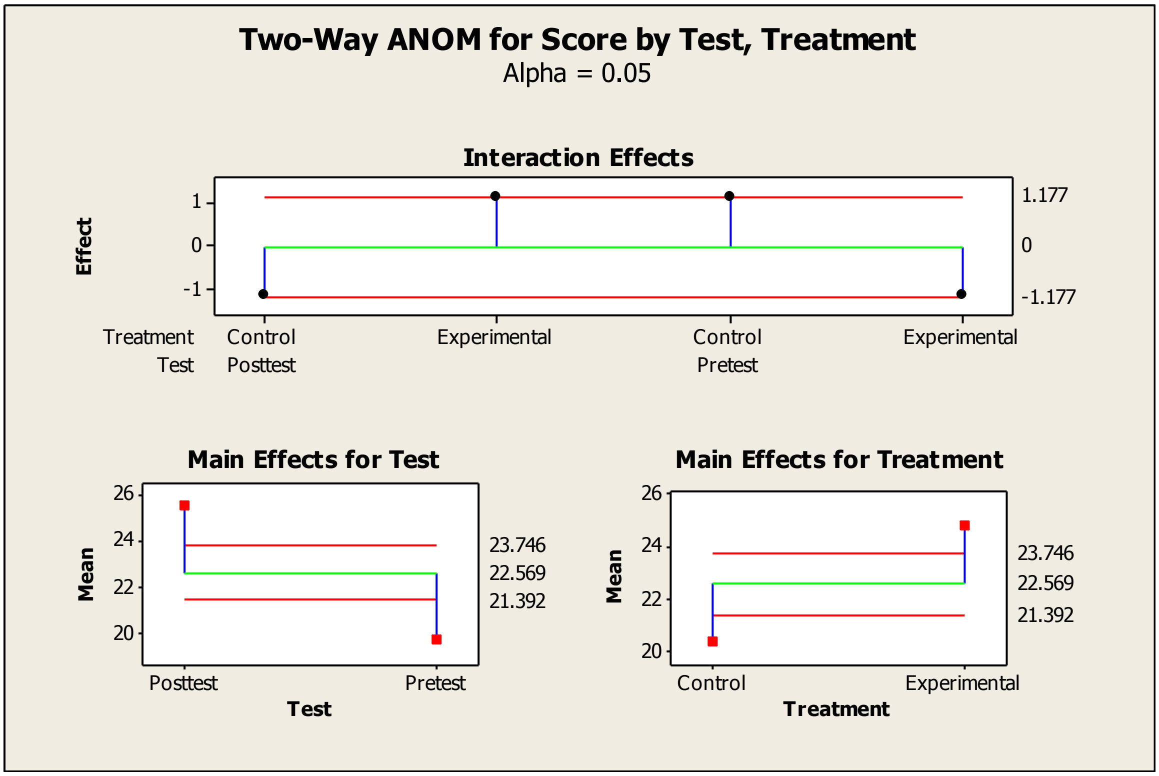
Two-way analysis of Mean was also done on the pretest and posttest performance (test) and the control and experimental group (treatment). This also showed significant difference in the test and treatment but no interaction effect as shown in the figure 3 below. The red dots indicate significant effect while the black dots indicate that there is no significant difference in the means

Discussion: Evidence from the findings of this study showed that collaborative learning had significant impact on students' performance in stoichiometry. The experimental group produced higher mean scores in the posttest than the control group. The finding of this study is in consonance with the view of Cross (2000) and other researchers who assert that collaborative learning enhances the attainment of pedagogical objective. In keeping with the proponents of collaborative learning students in the experimental group showed interest in solving problems in stoichiometry. The peer support fostered active participation and roused each student in the various groups to think of better ways of finding solution to stoichiometry problems. The peer group interaction exposed students' intellectual ability and responsibility to construct meaningful ideas during the learning process. Hence, students who had the initial concept that stoichiometry was difficult to understand were more relaxed with their peers and they equally performed better after treatment. This study further confirmed the findings of earlier researches with regards to the clear differences between the lecture method or "factory model" and collaborative learning. While traditional methods have little measurable effects on educational achievements of students (Hofstein, Lunetta, 1982), collaborative learning improves students' academic achievement, helps them develop better reasoning and critical thinking skills, ability to transfer prior knowledge to new situations, reduces stress levels, promotes more positive attitudes toward chemistry and improves student commitment and retention (Wenzel, 2007, 2000 & 1998).

Figure 3: Two-way analysis of mean for Students' score in mathematics for both test and treatment effect



5. Conclusion

Result from this study has provided empirical evidence of the efficacy of collaborative learning in promoting achievement gains, cognitive and affective skills among secondary school students. This suggests the need for chemistry teachers in Nigeria to structure chemistry lessons in such a way as to actively involve learners to participate collaboratively in the learning process. The persistent failure of students in chemistry presupposes that there is critical need to shift from traditional approaches to collaborative learning. This is essential because the world is rapidly becoming more complex and competitive. Hence, educational practices should be able to expose learners to strategies that would enable them become critical thinkers, problem solvers and socially responsible citizens. Against this background this study urges curriculum planners, teachers, stakeholders to encourage the implementation of collaborative learning in Nigerian schools.

References

Adeboyel, A. O. (1999). Interesting relationships between mathematics and science. *Journal of Mathematics and science,* 1(2), 22-29.

Arasasington, R., Taagepera, M., Poter, F., Martorell, I. & Lonjers, S. (2004). Assessing the effect of web-based learning on student understanding of stoichiometry using knowledge space theory. *Journal of Chemical Education,* 82, 1251-1262.

Badru, A. K. (2004). *Student performance in mathematics as correlate of their performance in chemistry.* 45th Annual Conference Proceedings of Science Teachers Association of Nigeria.

Bamidele, E. F. & Oloyede, E. O. (2013).Comparative effectiveness of hierarchical flowchart and spider concept mapping strategies on students' performance in chemistry. *World Journal of Education*, 3(1), 66-76
Bruffee, K. A. (1984). Collaborative learning and the conversation of mankind. College
Bruffee, K. A. (2009). Conjoined intelligence: Reading, writing, talk. Unpublished
Callahan, R. E. (1962). Education and the Cult of Efficiency. Chicago: Univ. Chicago Press
Chandrasegaran, A. L., Treagust, D. F., Waldrip, B. G. & Chandrasegarian, A. (2009). Students' dilemmas in reaction stoichiometry problem solving: deducing the limiting reagent in chemical reactions. *Chemistry Education Research and Practice,* 10, 14-23
Cross, K. P. (2000). Collaborative learning 101. The Cross Papers Number 4. Mission Viejo, CA: League for Innovation in the Community College. *English,* 46(7), 635-652.
Evans, K. L., Yaron, D. & Leinhardt, G. (2008). Learning Stoichiometry: A Comparison of Text and Multimedia Formats. *Chemistry Education Research and Practice*, 9(3), 208-218.
Fach, M., De Boer, T. & Parchmann, I. (2007). Results of an interview study as basis for the development of stepped supporting tools for stoichiometric problems*. Chemistry Education Research and Practice*, 8(1), 13-31
Furio, C. O., Azcona, R. & Guisasola, J. (2002). The learning and teaching of the concepts amount of substance and mole: A review of the literature. *Chemistry Education Research and Practice*, 3, 277- 292
Gamson, Z. F. (1994). Collaborative learning comes of age*. Change,* 26(5), 44-50.
Gauchon, L. & Meheut, M. (2007). Learning about stoichiometry: from students, preconceptions to the concept of limiting reactant. *Chemistry Education Research and Practice*, 8(4), 362-375
Hofstein, A. & Lunetta, V. N. (1982). The role of the laboratory in teaching: Neglected aspects of research. *Rev. Educ.*, 52, 201-217
Holt, M. D. (1988). Collaborative learning from 1911-1986: A socio-historical analysis (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses database. (AAT8901334)
Hopko, D. R. (2003). Confirmatory factor analysis of the math anxiety rating scale-revised. *Educational and Psychological Measurement,* 63(1), 33-46
Kelly, W. P. & Tomhave, W. K. (1985). A study of maths anxiety/math avoidance in pre-service elementary teachers. *Arithmetic Teacher*, 32(5), 51-53
Krammer, P. H. (2000). Recurrent Difficulties Solving Quantitative Problems. *Journal of Chemistry Education,* 59(6), 509-512.
Lave, J. & Wenger E. (1999). Situated Learning : Legitimate Peripheral Participation. Cambridge: Cambridge Univ. Press manuscript, Department of English, Brooklyn College of City University, New York, NY. .
Nwosu, A. A. (2004). Teachers' awareness of creativity related behaviors science classroom. *Journal of* Sc*ience Teachers' Association of Nigeria*, 39(1&2), 22-26
Opara, M. F. (2013). Application of the learning theories in teaching chemistry: Implication for global competitiveness. *International Journal of Scientific and* Engineering Research, 4(10), 1224-1243
Parker, B. P. (1983). Mc Graw Hill Encyclopedia of Chemistry. Mc Graw Hill Book Company, New York
Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering* Education*,*93(3), 223-231.
Rogoff, B. (2003). The Cultural Nature of Human Development. New York: Oxford University Press.
Rogoff, B., Matusov, E. & White, C. (1996). Models of teaching and learning: participation in a community of learners. In Handbook of Education and Human Development: New Models of Learning, Teaching, and Schooling, ed. D Olson, N Torrance, pp. 388–414. London : Blackwell
Salman, M. F., Olawoye, F. A. & Yahaya, L. A. (2011). Education reforms in Nigeria : Implications for girl child participation in science, technology and mathematics (STM). *Education Research Journal*, 1(1), 1-8.
Sfard, A. (1998). On two metaphors of learning and the dangers of choosing just one. *Educational Researcher*, 27(2), 4-13.
Silverman, S. L. & Casazza, M. E. (2000). Learning and development. San Francisco, CA: Jossey-Bass
Stuart, V. (2000). Maths curse or math anxiety? *Teaching Children Mathematics*, 6, 330 – 335
Udosoro, U. J. (2011).The Effects of gender and mathematics ability on academic performance of students in chemistry. *African Research Review: An International Multidisciplinary Journal, Ethiopia*, 5(4), 201-213
Vygostky, L. S. (1975). Mind in Society : The development of higher mental processes. Cambridge M. A: Harvard University Press.

Wenzel, T. J. (1998). Cooperative group learning in undergraduate analytical chemistry. *Analytical Chemistry*, 70, 790A-795A
Wenzel, T. J. (2000). Cooperative Student Activities as Learning Devices. *Analytical Chemistry*, 72, 293A-296A
Wenzel, T. J. (2007). Peer- Assessment and Self- Assessment of Group Activities. *Journal of Chemical Education*, 84, 182-186
West African Examinations Council Senior Certificate Examinations May/June (2002 – 2012) ,Chief Examiners' Report
Woolfolk, A. & Margetts, K. (2013). *Educational Psychology*.3rd Ed NSW Pearson Australia. 95-100' 323