Effect of Problem-solving Teaching Technique on students' Stoichiometry Academic Performance in Senior Secondary School Chemistry in Nigeria.

ABSTRACT

Aims: This study addressed the effect of problem-solving technique on students' academic performance in stoichiometry in Senior Secondary Schools in Port Harcourt, Rivers State Nigeria.
Study design: Quasi-experimental design specifically pre-test post-test control groups non-randomized design was adopted.
Place and Duration of Study: Senior Secondary Schools in Port Harcourt Local Government Area of Rivers State located at the South-South Geopolitical Zone of Nigeria and lasted for four weeks.
Methodology: The population comprised of 520 senior secondary 2 chemistry students from private and public schools. 105 SS2 chemistry students representing 61 males and 44 females from intact classes of selected schools formed the sample*.* The instrument was Stoichiometry Achievement Test developed by the researcher and reliability coefficient calculated to be 0.79. Three research questions and three hypotheses were used in the study. Mean and standard deviation were used to answer the research questions while the hypotheses were tested using Analysis of Variance at .05 level of significance.
Results: Findings of the study revealed a significant difference in performance between students taught stoichiometry using problem-solving technique (experimental) and those taught using conventional lecture method (control). Students exposed to problem-solving technique obtained higher score in performance test than those in conventional lecture method. Furthermore, there was a significant difference in students' performance based on gender (male and female) and school type (private and public).
Conclusion: The study therefore, concludes that problem-solving technique is more effective and enhance students understanding than traditional lecture method. The study recommended that chemistry teachers should incorporate problem-solving in teaching stoichiometry and related concepts and present curriculum should be reviewed to recommend problem-solving technique*.*

Keywords: Problem-solving technique, stoichiometry, chemistry students, academic performance

1. INTRODUCTION

Chemistry occupy a central position in the field of science and provides basic concepts for understanding complex chemical reactions utilized in industries for production of numerous products for the benefit of man and technological development mostly in developing countries like Nigeria. Other sciences, medicine, engineering, and related courses depend on the knowledge of chemistry for effective functioning of their profession. Stoichiometry is a concept in chemistry that has wide range of industrial applications because it establishes the relationship between the amount of reactants and the products in a given reaction. It entails the use of mathematical expressions to determine the amount of reactants and products in a known reaction which is usually represented as mass or volumes and expressed in moles. The amount in moles can be converted to grammes or volumes depending on the state of the reactants and the products. The concept of stoichiometry though challenging to students, plays an indispensable role in providing basis for proper understanding of related concepts in chemistry. Adequate understanding of reaction stoichiometry is fundamental to improved performance of students in practical chemistry, particularly quantitative or volumetric analysis which involves calculation of masses and volumes. Stoichiometry according to [1] is the study of quantitative aspect of mass-mole number relationship, chemical formulae and reactions which involves mole concepts and balancing of chemical equations. By implication, the relationship between the amount of reactants and products represents the stoichiometry of the reaction and is usually expressed in moles in a given reaction.

Concepts in stoichiometry contains mathematical expressions which require problem-solving and high-level thinking skills to enhance understanding of facts because of the mathematical calculations involved in determining the amount of substance. Problem solving can be defined as a process whereby someone applies previously learned rules to a novel situation in order to arrive at a solution [2]. It requires application of both tacit and explicit knowledge to manipulate information for understanding of requirements of given problem. The knowledge possessed by students should be relevant to the problem at hand and well-structured or organized and transferable to the problem situation. Consequently, teachers need to understand how and which knowledge is used to arrive at a particular answer or even when correct answer is not attained, assessment of process applied should lead to understanding student's processes. Students' understanding of problem is achieved when the student's knowledge has coherence and cohesion to recognize and prevent use of different and conflicting elements of knowledge [3]. This occurs when students are able to bring together parts of their prior knowledge about the new situation and make sense of what it entails. Problem-solving instruction is a constructivist-based student-centered instruction founded on the principle of learning by doing and by experiencing which emphasizes on learners' construction of knowledge for meaningful learning. The process of knowledge construction by students facilitates proper understanding and retention of information because the information learned is a product of their personal construction. This is opposed to the traditional lecture method where the process of acquiring knowledge involves rote memorization of chemical formulae and specific reaction. In this case knowledge is not applicable to the knowledge already learned which constitute a problem to leading to cognitive dissonance where facts are separated entities with no relationships. Cognitive dissonance which can be described as having knowledge without being able to use it. The constructivist learning theory provides basis for this study and describe knowledge as the basis on which new learning is constructed. That is, knowledge is considered as the tool that the learning object uses to construct new meanings in the process of 'knowing' [2].

Teachers play an essential role in promoting students' understanding of stoichiometry which prevent them from perceiving the concepts as a difficult. This can be achieved by adopting teaching methods that encourage active engagement of the learner, focusing on the learner rather than teacher, and acknowledging as well as challenging learners' understanding/intellectual development and the interaction among these domains [4]. Students' difficulties in solving stoichiometric problems must be explored to enable teachers design appropriate instructional strategies that will address students' difficulties and enhance understanding of the concept. There are useful pedagogical strategies that can facilitate meaningful learning of reaction stoichiometry of which problem-solving technique is one of them. [1] appraising his experiences while teaching stoichiometry to students in grade 10 and 11 in Mid-Western Urban School District in United States of America with qualitative narrative approach and face to face interview opined that teachers should adapt their instructional strategies and modes of delivery to reflect students' individual learning styles and be knowledgeable, creative, and resourceful in their subject area to help students learn stoichiometry. There are several approaches for teaching science concepts, but the suitability of a given or combination of methods depends on the topic because the method suitable for one topic may not necessarily be suitable if applied to another topic. Therefore, each method is unique in its ability to solve academic problem. There are various models of problems solving based teaching strategies in chemistry. These models are very useful in improving students' problem-solving abilities. A good example is the model developed by [5] which involves the following stages:

- Defining the goal of the problem
- Selecting information from problem statement
- Selecting information from the memory
- Reasoning; and
- Error in computation

Furthermore, [6] developed a four-stage model for solving chemistry problems based on the heuristic for easy application by students to alleviate the burdens of memorizing different relationship or formulae relating to different topics by providing the key- relations chart. The four stage- model otherwise known as WISE include:

- What is happening?
- Isolation of unknown
- Substitute given values
- Evaluate.

[7] developed a model which consist of four steps:

- Understanding the problem (recognizing what is asked for). For instance, asking yourself what am I looking for? or what information is given in the problem?
- Devising a plan for solving the problem (responding to what is asked for). For instance, ask questions such as do I know a similar problem? can I state the problem?
- Carrying out the problem (developing the results of the response) and,
- Looking g back (checking. What does the results tell me?).

Another model is the dimensional analysis devised to solve problems in stoichiometry which utilizes conversion factor in the stoichiometric calculations and set up a joined relationship for solution. These conversion factors are provided by mole concept for problem-solving. The equations or conversion factors are set up in fraction form and lined up sequentially such that the units on top and bottom of neighbouring fractions are alternated for the units cancel. On the other hand, the mole method involves step by step calculation of amounts from the given quantity through the moles to amount of the unknown. In a given reaction, chemical equations are represented in moles not in masses. Therefore, the moles must be converted to mass to calculate the mass of product from a known mass of the reactant by comparing the given number of moles of reactants to the number of moles of the product and finally converting moles to mass of product. The dimensional analysis and mole method obtain results from the quantity through the mole of the given and unknown substance. The expression below shows the sequence in the conversion form mole to mass.

Mass   mass
Given volume → given moles → wanted moles → wanted volume
Number   number

Figure 1: Outline for dimensional analysis and mole method

The last strategy is the proportion or algorithmic method which compares the given amounts to the unknown amount and set up a relation between these amounts. This method emphasizes basic scientific principles through application during the process of solving problems which in turn promotes students' understanding of these principles by constantly reinforcing basic concepts

Several researches have been carried out to investigate the effectiveness of problem-solving method in enhancing students' understanding of the concept of stoichiometry. For instance, [8] Mandina & Ochonogor (2017) attempted to remedy the difficulties encountered by high school chemistry students when solving stoichiometric problems by using problem-solving approach on 485 advanced level learners high school students in Gweru District of Zimbabwe. Results of the study showed that, the use of problem-solving instruction was an effective strategy in remedying the identified difficulties in comparison to the conventional lecture method. There was a significant difference between the mean score of students exposed to problem solving models and those in the conventional lecture method. The instrument was Stoichiometry Achievement Test (SAT). [9] investigated the effect of enhanced problem-solving technique on students' competence in tackling chemical problems. Quasi experimental design was adopted and 120 senior secondary 2 students of Ekiti state used as sample. Result of the study showed that students exposed to enhanced problem-solving technique performed better than those exposed to lecture method. Further findings of this study revealed that it is better for students to learn the art of solving problem in a relaxed atmosphere by providing them with formulae and equations required. To guarantee this, students should be made to understand the relationship between the physical quantities that make up the atmosphere.

Apart from stoichiometry, the effectiveness of problem-solving instruction in enhancing students' performance in chemistry have also been validated. For instance, [10] explored the effects of problem-solving instructional strategy, three modes of instruction and gender on learning outcomes in chemistry. The sample was 210 SS2 chemistry students of Ekiti State, Nigeria and the model was Seven Step Chemistry Problem-Solving Model (SSCPSM) suggested by [11] and [3]. Findings of the study revealed that students in experimental group (i.e problem-solving coupled with remediation) had the highest scoresin chemistry achievement test compared to the conventional lecture method. There was no significant difference in students' performance based on gender.

[12] investigated the relative effectiveness of two problem-solving models ([13]-[11] and [5]) programmed student learning model in facilitating students' learning outcomes in chemistry using 275 college of education students in Oyo and Ogun State, Nigeria as the sample. The findings of the study revealed that students who were taught with problem-solving models either teachers'-directed or students'-directed, performed significantly better than their counterparts in control group that were taught with formula method. Gender was found to affect students' cognitive achievement and attitude towards learning chemistry. Insignificant interaction effect of treatment and gender at effective level was also established.

[14] investigated the effects of problem-solving instructional strategy and numerical ability on students' learning outcomes using Seven Step Chemistry Problem-Solving Model (SSCPSM) and 201 chemistry students selected by multi-stage random sampling technique from secondary schools in three local Government' Areas of Ekiti State of Nigeria. Findings of the study revealed that problem-solving instructional strategy as well as students' numerical ability improves students' performance in chemistry confirming that problem-solving approach was more effective and reliable method of teaching than conventional

lecture method. The study also showed that students with high numerical ability performed better than their counterparts with low numerical ability. Male and female students of high and low ability levels did not differ in their performance in chemistry at group levels.

Other researchers focused on the effect of other methods of teaching on students' performance in stoichiometry. In this regards, [15] explored the influence of process oriented guided inquiry learning (POGIL) on science foundation students' achievement in stoichiometry problems at university of Namibia and found that The POGIL group student also recorded the highest improvement on questions related to stoichiometry and limiting agents and were able to give correct reasons for their answers obtained through numerical calculations or multiple choice while demonstrating enhanced understanding of the linking stoichiometry concepts compared to the traditional group. There was a significant statistical difference in achievement between the POGIL group and lecture group of students.

[16] in his comparative study of the effectiveness of flipped classroom and traditional classroom instruction and found that flipped classroom instruction was effective in teaching stoichiometry compared to traditional lecture method. Significant difference between the flipped classroom and traditional classroom instruction on students' conceptual change on stoichiometry was established. Students response to the flipped classroom instruction was largely positive indicating it to be worthy approach for teaching stoichiometry. [17] developed a theoretical framework based on history and philosophy of chemistry to facilitate high school grade 10 students' understanding of stoichiometry in Venezuela using dialectic constructivist strategy based on the presentation of hypothetical experimental data and found that students in the experimental group performed better than those in the control group, not only on algorithmic items but also items requiring conceptual understanding. There was a statistically significant difference in students' performance between the experimental and control group. History and philosophy of chemistry perspective developed

in this study led to a critical evaluation of laws of definite proportion and their role in chemistry education.

[18] explored approaches to dealing with difficulties undergraduate students experience with stoichiometry in Tshwane University of Technology South Africa using 456 first year chemistry students of Taiwanese University of Technology (TUT) and worksheet intervention model designed based on research. Findings of the study showed that structured worksheet together with tactile models showed a remarkable improvement in undergraduates' understanding of the concept of stoichiometry. [19] studied the effects of mathematical reasoning skills on students' achievement in chemical stoichiometry using 400 senior secondary school students of Oshimili South Local Government area of Delta State Nigeria as sample and Chemistry Achievement Test. Results of the study showed that there was a significant difference in achievement in stoichiometry as a result of mathematics instruction, entering mathematics skills and achievement in chemical stoichiometry. Furthermore, mathematics skills correlated significantly with achievement in chemical stoichiometry. There was significant gender difference in students' achievement in mathematics and chemical stoichiometry. A significant improvement in chemical stoichiometry was recorded after remediation.

Science subjects and related courses are usually dominated by the male students' and many assertions tends to establish difference or no difference in gender performance in sciences mostly those that involves mathematical and related disciplines like engineering. In this regard, [20] investigated the differences between male and female students' performances in Biology, Chemistry and Physics among pre-degree students of Federal University Dutsin-ma, Katsina State-Nigeria. The results of the study showed that there were no significant differences in the performance of male and female students in biology, chemistry and physics. [21] compared male and female senior secondary school students' learning outcomes in science in Katsina State, Nigeria using 204 students randomly selected from the three geopolitical zones of the state. The findings of the research showed that there were no significant difference between male and female students in overall science achievement attitude to science and also biology, chemistry and physics achievements. [22] in their research to find out if sex differences exist in calculating reacting masses from a set of chemical equations among secondary school students in Makurdi metropolis found that boys performed better than girls on the achievement test.

1.1 Statement of the Problem

Stoichiometry contains numerical problems which entails the use of mathematical expressions to determine link between two or more parameters and find solution to chemical problems. Unfortunately, concept difficulty in stoichiometry and students' poor performance in certificate examinations has been established. In support of this, [23] reported students' poor performance in stoichiometry and chemical reactions in May/June Senior Secondary School Certificate Examination. The observed poor performance of students could be attributed to factors which are either teacher or student related. The use of appropriate teaching method enhances students' understanding of concepts which results in good performance while use of wrong method lead to difficulty in understanding and cause poor performance. The question therefore is, which teaching method will be effective to address students' concept difficulty and poor performance in stoichiometry? In providing answer to this question, several teaching approaches have been adopted but models of problem-solving approach have not been fully explored leaving a gap in knowledge. This study therefore, intends to bridge the gap by investigating the effect of problem-solving technique (WISE model) on students' academic performance in stoichiometry in senior Secondary School in Rivers State.

1.2 Purpose of the Study

This research was carried out to evaluate the effect of problem-solving technique on students' academic performance in stoichiometry in senior secondary schools in Rivers State. Specifically, the study tends to determine the:

1. performance of students taught stoichiometry with problem-solving technique and those with conventional lecture method in Senior Secondary School in Rivers State.
2. performance of male and female students taught stoichiometry with problem-solving technique and those taught with conventional lecture method in Senior Secondary School in Rivers State?
3. performance of public and private school students taught stoichiometry with problem-solving technique and those taught with conventional lecture method in Senior Secondary School in Rivers State?

1.3 Hypotheses

HO_1. There is no significant difference in performance between students taught stoichiometry with problem-solving technique and those taught with conventional lecture method in Senior Secondary School in Rivers State.

HO_2. There is no significant difference in performance between male and female students taught stoichiometry with problem-solving technique in Senior Secondary School in Rivers State?

HO_3. There is no significant difference in performance between public and private school students taught stoichiometry with problem-solving technique in Senior Secondary School in Rivers State.

2. MATERIAL AND METHODS

Quasi-experimental experimental design using pre-test post – test control group was adopted. The population of this study was 520 senior secondary 3 chemistry students from 57 private and 48 public schools in Port Harcourt Local Government Area of Rivers State. 105 SS2 chemistry students consisting of 61 males and 44 females from intact classes of selected schools formed the sample. No sampling was done because intact classes were used in the study. The two intact classes in each selected school were used for the study and randomly assigned experimental and control groups. The total number of students in the experimental groups were 53 and control group 52. The instrument was a 20-item multiple choice Stoichiometry Achievement Test (SAT) developed by the researcher. Test items were selected from past question papers of WAEC Senior Secondary School Certificate Examination (SSCE) and subjected to face and content validation by two lecturers in Science Education Department and one lecture in Measurement and Evaluation. The reliability coefficient was determined by test–retest method and coefficient found to be 0.70. Mean and standard deviation were statistical tools used to answer research questions while Analysis of Variance was used to test the hypotheses at .05 level of significance. Students in the experimental group were taught using problem-solving instruction and those in the control group with conventional traditional lecture method. The instrument was administered as pre-test before treatment and post-test after treatment and data used for analysis.

3. RESULTS

Research Question 1.

What is the performance of students taught stoichiometry with problem-solving technique and those with conventional lecture method in Senior Secondary Schools in Rivers State?

Table1 showed that the pre-test mean performance scores of students taught stoichiometry with problem solving-technique and those taught with conventional lecture method were 38.17 and 40. 67 respectively with standard deviations of12.36 and 9.56. Also, the post-test mean performance score of students taught stoichiometry with problem solving-technique and those taught with conventional lecture method were 54.43 and 42.81 respectively with standard deviations of17.46 and 17.36. Students in the problem-solving technique recorded higher mean performance score and higher standard deviation than those in the conventional lecture method after treatment.

Table 1. Mean and standard deviation analysis of performance of students taught stoichiometry with problem-solving technique and those taught with conventional lecture method.

		Mean			Standard Deviation		
Group	**N**	**Pre-test**	**Posttest**	**Diff.**	**Pre-test**	**Post-test**	**Diff.**
Experimental	53	38.17	54.32	16.15	12.30	17.36	10.01
Control	52	40.67	42.81	2.14	9.56	18.27	6.03
Diff. between		2.50	1.51	4. 01	2.74	0.91	3.98

Research Question 2.

What is the performance of male and female students taught stoichiometry with problem-solving technique in Senior Secondary School in Rivers State?

Table 2 showed that the post-test mean performance score of male and female students taught stoichiometry with problem solving-technique were 53.08 and 40.30 respectively with standard deviations of 19-15 and 15.96. Male students taught stoichiometry using problem solving technique recorded higher mean performance score and higher standard deviation than female students.

Table 2. Mean and standard deviation analysis of performance of male and female students taught stoichiometry with problem-solving technique in Senior Secondary Schools in Rivers State.

Gender	N	Mean	Std. Deviat
Male	31	53.08	19.15
Female	22	40.30	15.96
Difference		12.78	3.19

Research Question 3

What is the mean performance of public and private school students taught stoichiometry with problem-solving technique in Senior Secondary School in Rivers State?

Table 3 showed that the post-test mean performance score of private and public school students taught stoichiometry with problem solving-technique were 54.86 and 42.23 respectively with standard deviations of 18.16 and 15.14. Private secondary school students taught with problem-solving technique recorded higher mean performance score and higher standard deviation than public secondary school students.

Table 3. Mean and standard deviation analysis of performance of public and private school students taught stoichiometry with problem-solving technique in Senior Secondary Schools in Rivers State.

School Type	N	Mean	Std. Deviation
Private	57	54.86	18.16
Public	48	42.23	15.14
Difference		12.63	3.02

3.2 Hypothesis 1

There is no significant difference in performance between students taught stoichiometry with problem-solving technique and those with conventional lecture method in Senior Secondary School in Rivers State.

From Table 4, the calculate value of F-ratio = 11.477 is greater than the table value (p = .05). Therefore, the null hypothesis which states that there is no significant difference in performance between students taught stoichiometry using problem-solving technique and traditional lecture method in senior secondary school rejected. This infers that there is a significant difference in performance between students taught stoichiometry using problem-solving technique and conventional lecture method in senior secondary schools in Rivers State.

Table4. ANOVA of the post-test experimental and control mean performance of students taught stoichiometry using problem-solving technique and those taught with lecture method in senior secondary schools in Rivers State.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	3479.138	1	3479.138	11.477	.001
Within Groups	31223.624	103	303.142		
Total	34702.762	104			

3.3 Hypothesis 2

There is no significant difference in performance between male and female students taught stoichiometry with problem-solving technique in Senior Secondary School in Rivers State.

From Table 5, the calculate value of F-ratio = 13.061 is greater than the table value (p = 0.05). Therefore, the null hypothesis which states that there is no significant difference in performance between male and female students taught stoichiometry with problem-solving technique in Senior Secondary Schools in Rivers State is rejected. This infers that there is a significant difference in performance between male and female students taught stoichiometry with problem-solving technique in Senior Secondary Schools in Rivers State.

Table 5: ANOVA of the post-test mean score of male and female students taught stoichiometry using problem-solving technique in senior secondary schools in Rivers State.

Source of variance	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4179.241	1	4179.241	13.061	.000
Within Groups	32957.749	103	319.978		
Total	37136.990	104			

3.4 Hypothesis

There is no significant difference in performance between public and private school students taught stoichiometry with problem-solving technique in Senior Secondary School in Rivers State?

From Table 6, the calculated value of F-ratio = 14.641 is greater than the table value (p = .05). Therefore, the null hypothesis which states that there is no significant difference in performance between public and private school students taught stoichiometry with problem-solving technique in Senior Secondary School is rejected. This infers that there is that there is a significant difference in performance between public and private school students taught stoichiometry with problem-solving technique in Senior Secondary School in Rivers State.

Table 6. ANOVA of the mean score of public and private school students taught stoichiometry with problem-solving technique in senior secondary schools in Rivers State

Source of Variance	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	4156.872	1	4156.872	14.641	.000
Within Groups	29243.356	103	283.916		
Total	33400.229	104			

4. Discussion of Findings

Evidence from the findings of this study revealed a significant difference in performance between students taught stoichiometry with problem-solving technique and those taught with conventional lecture method (Table5). Students taught with problem-solving technique performed significantly better in the performance test than those taught with conventional lecture method. Results of this study corroborates the findings of other studies on the effect of problem-solving instruction on students' performance in stoichiometry by [19], [24] and [9] where significant differences in performance between students taught stoichiometry with problem-solving technique and conventional lecture method were established in their independent studies. Students in the experimental group where lesson was delivered by problem-solving technique performed better because they achieved good reasoning and process skills in calculations which enhance their mathematical skills and enable them to solve algorithmic problems in stoichiometry. This validate, [19]'s claim that mathematics skills correlated significantly with achievement in chemical stoichiometry and [14] assertion that students with high numerical ability performed better than their counterparts with low numerical ability in chemistry and students' numerical ability improves students' performance in chemistry. Furthermore, students in the problem-solving instruction classroom, utilized both fact and explicit knowledge acquired in the process of problem-solving instruction to manipulate information and understand what is required in the problem as they are exposed to meaningful learning. According to [25], this is the knowledge that is responsible for interactions involved in problem-solving or the process of knowing as students engage or attempt to solve chemical problems. In the control group, where students were exposed to traditional lecture method, students were not involved in the process of knowledge construction instead they played a passive role in the classroom depending on the teacher as the source of information. Knowledge is not personalized but transferred by repeated act of memorization resulting in poor retention and retrieval of information. The students attempt to solve chemical problems through rote memorization and recall of information which translates into difficulty in understanding and the low scores obtained in the stoichiometry test.

There was a significant difference in performance between male and female students taught stoichiometry with problem solving technique. Male students performed significantly better than female students in the performance test. This results in agreement with that of [19] who found a significant gender difference in students' performance in stoichiometry and further gives credence to the assertion that males possess better mathematical skills and perform better in concepts that involves calculations than the females. The results however, disagree with the findings of [14] and [10] where no significant gender difference in students' performance in stoichiometry was found. Finally, there was a significant difference in performance between private and public secondary school students in stoichiometry.

Private secondary school students performed significantly better in the performance test than public secondary school students.

5. CONCLUSION

The outcome of this study confirms that Problem-solving technique is effective and enhance students' understanding of concepts in stoichiometry than conventional lecture method. There was a significant difference in performance between students taught stoichiometry with problem-solving approach and those taught with conventional lecture method. Students' taught with problem solving technique performed significantly better than those taught with conventional lecture method. Furthermore, there was a significant difference in performance of students based on gender (male and female) and school type (private and public).

6. Recommendations

Based on the findings of this study the following recommendations were made.

1. chemistry teachers should in cooperate problem-solving learning to improve student's understanding.
2. chemistry curriculum should be reviewed to accommodate problem-solving and activity oriented instructional strategies.
3. chemistry educators should understand students' difficulties and implement problem solving pedagogies technique to address students' difficulties in solving problems on stoichiometry.

CONSENT

As per international standards, or university standards, students' written consent has been collected and preserved by authors.

COMPETING INTERESTS

Authors have declared that no competing interest

REFERENCES

1. Bridges CD. Experiences teaching stoichiometry to students in Grade 10 and 11. Published Doctoral Dissertation: Walden University; 2015.

2 Cook E & Cook RL. Cross-proportions: A conceptual method for developing quantitative problem-solving skills. Journal Chemistry Education. (2005); *82*(8):118.

3. Koponen IT & Huttunen L. Concept development in learning Physics: The case of electric current and voltage revisited. Science & Education. 2012; 1191-2012.

4. Ayoade EO. Bridging theory and practice: Application of constructivist tenets to teaching of reaction stoichiometry. International Journal of Science and Technology. 2012; 1(1): 144-163.

5 Ashmore AD, Frazer MJ & Casey RJ. Problem solving network in Chemistry. Chemistry Education. 1979; *56*(6): 377-379.

6. Williams DS & Wright CD. A wise-strategy for introductory physics. Physics Teachers. 1986:211-216.

7. Polya G. *How to solve it*, 2nd ed. USA: Princeton University Press. 1957.

8 Mandina S & Ochonogor CE. Using problem-solving to overcome high school chemistry students' difficulties with stoichiometric problems. African Journal of Educational Studies in Mathematics and Sciences. 2018: 13, 33 -39.

9. Canon-Jegede, SA. The effect of problem-solving technique on students' competence in tackling chemical problems. Research Journal of Applied Sciences. 2007; 2(7): 80.

10. Jegede SA & Fatoke AO. Effects of problem-solving instructional strategy, three modes of instruction and gender on learning outcomes in chemistry. Journal of Education and Practice. 2014; 5 (23): 179-184.

11. Frazer MJ. Solving chemical problems: Nyholm Lecture. Sarile Row and London W.I. 1982.

12. Raiami SM. & Babayemi JO. Relative effectiveness of two problem- solving models in facilitating stduents' learning outcomes in chemistry. In perspective of Nigerian Education (Eds I.O. Salau, A. I. Ikeoguonye and Inegbegion). 2013: 317-332.

13. Selvarantnam M. Students' mistakes in problem-solving. Education in Chemistry. 1983 7:125-130.

14. Fatoke AO, Ogunlade TO. & Ibidiran VO. The effects of problem-solving instructional strategy and numerical ability on students' learning outcomes. International Journal of Engineering and Sciences (IJES). 2013;2 (10): 96- 102.

15. Kaundjwa AOT. Influence of process oriented guided inquiry learning (POGIL) on science foundation students' achievement in stoichiometry problems at university of Namibia. Published master Degree Thesis: University of South Africa. 2015.

16. Gayeta NE. Flipped classroom as an alternative strategy for teaching stoichiometry. Asia Pacific Journal of Multidisciplinary Research.2017; 5(4): 83-89.

17. Niaz M & Montes LA Understanding stoichiometry: Towards a history and philosophy of chemistry. Educations Quimica publications. 2012: 1-8.

18. Marais F & Combrinck S. An approach to dealing with the difficulties undergraduate chemistry students experience with stoichiometry. South African Journal of Chemistry. 2009: 62, 88-89.

19 Adigwe JC. Effects of mathematical reasoning skills on students' achievement in chemical stoichiometry. Review of Education Institute Education of Journal. 2012;23(1): 1-22.

20. Ibrahim ST, Sabitu A. & Magaji YM. Comparative Analysis of Gender Performances in Biology, Chemistry and Physics among Pre-Degree Students of Federal University, Dutsinma. International Journal of Educational Benchmark (IJEB). 2016: 108-118.

21. Olasehinde KJ & Olatoye RA. Comparison of Male and Female Senior Secondary School Students' Learning Outcomes in Science in Katsina State, Nigeria. Mediterranean Journal of Social Sciences. 2014; 5 (2): 517-523.

22. Eriba JL & Ande S. Gender differences in achievement in calculating reacting masses from chemical equations among secondary school students in Makurdi Metropols Educational Research and Reviews. 2006; 1 (6): 170-173.

23. West African Examinations Council. Chief examiner's report. The West African Examinations Council. 2017.

24 Shedreck M Enunwe OC. Problem solving instruction for overcoming students' difficulties in stoichiometric problems. African Journal of Educational Studies in Mathematica and Sciences. 2018:14, 25-31.

25. Hallett D, Nunes T, Bryant P & Thorpe CM. Individual differences in conceptual and procedural fraction understanding: The role of abilities and school experience. Journal of Experimental Child Psychology. 2012;113: 469-486.

APPENDIX