



Student's Learning Difficulties in Stoichiometry: Sources and Strategies for Resolving them

Eya, Ngozi M. & Ugah, C. Kosisochukwu

Department of Science Education, University of Nigeria Nsukka

Corresponding author: ngozi.eya@unn.edu.ng

Abstract

Stoichiometry has been identified as one of those topics that pose difficulties to chemistry students at secondary and tertiary institutions. This paper discussed the sources of learning difficulties in stoichiometry as well as strategies for resolving them. The sources of learning difficulties identified were- abstract nature of concept, mathematical nature of concepts, misconception and lack of problem solving skills. Innovative/student-centered strategies for resolving these difficulties discussed in the paper include- process oriented guided inquiry learning (POGIL), collaborative learning, problem solving and computer assisted instruction (CAI) It was recommended that all chemistry teachers should integrate these strategies so as to improve the students' conception of stoichiometry and overall learning outcomes in chemistry.

Introduction

Chemistry is many times depicted as the focal science. It is the study of matter, its composition, uses and transformations they undergo. It is a branch of science which deals the study of matter and the interactions between matter (Igboanugo, Igboegwu, Attah & Okonkwo, 2018). Most of our day-to-day activities revolve around chemistry. It is very essential for meeting our basic needs of food, clothing, shelter, health, energy, and clean air, water, and soil. it is prerequisite for the study of all science courses in the higher institutions (Njoku & Eze-Odurukwe, 2015). Hence the knowledge and good background in chemistry is essential for all science students. It plays vital role in the economical and national development of any nation.

Despite the importance of chemistry, students still perform poorly in the subject. This has been attributed to several factors of which students' learning difficulties is one of them. Studies show that several topics in chemistry has been found to pose difficulties to students. Prominent among these topics is stoichiometry (Shadreck & Enunwe, 2018; Etokeren, Inibehe & Alamina, 2019).

Stoichiometry deals with the study of the relative quantities of reactants and products in chemical reactions and how to calculate those quantities (Brown, LeMay, & Bursten, 2013). There are lots of documented importance of stoichiometry both at schools and in the chemical industry (Brown, 2015, Ogembo, 2017; Madina & Ochonogor, 2018). Brown (2015) described it as the heart of chemistry. Etokern, Ibemenji and Alamina (2019) asserted that stoichiometry finds numerous usefulness in the chemical industries because it establishes a connection

between the amount of reactant and products in a given chemical change. The researchers further stated that concept of stoichiometry though is very challenging to students, plays an important role in providing basis for proper understanding of related concepts in chemistry. Hence Knowledge and good mastery of stoichiometric concept is essential for all students who offer chemistry in secondary schools and in higher institution. Stoichiometric concepts constitute a large part of chemistry curriculum and students' inability to solve problems in it may have led to the poor achievement recorded in the subject over the years. Fach, De Boer and Parchman (2007) and Haider and Al Naqabi (2008) noted that students lack conceptual understanding of the stoichiometry concept; and have relied mostly on algorithm to solve problems on it .Hence, there is need to implement innovative strategies so as to resolve students' learning difficulties in this topic.

Several researches have been done to ascertain the effective pedagogical strategies that can facilitate meaningful learning of stoichiometry. Some of these studies include; problem solving teaching technique (Mandina & Ochonogor, 2018), cooperative learning (Kusi, 2013), collaborative learning (Opara, 2014), process oriented guided enquiry learning (Kaundjwa, 2015) and flipped classroom (Gayeta (2017). These works seek to discuss how these strategies among other strategies can be employed to resolve these lingering issues of students' learning difficulties in stoichiometry. The researcher believes that if the issues of chemistry students' stoichiometric learning difficulties are resolved, it could lead to an overall improvement in students' achievement in chemistry.

Concept of Stoichiometry

The term 'stoichiometry' was coined out from Latin words 'stoikhein' meaning element and 'metron' meaning measure. It deals with the use of connections among reactants and products in a chemical change to decide the ideal quantitative information. It depicts the quantitative connections among elements in compounds (composition stoichiometry) and among substances as they go through chemical changes (reaction stoichiometry). Ajayi (2017) described stoichiometry as a part of Chemistry that deals with calculations about the masses, or volume of reactants and products involved in a chemical reaction. In a given chemical reaction, Stoichiometry tells us what quantity of each reactant we need in order to get enough of our desired product(s). It is the study of quantitative aspects of the mass-mole number relationship, chemical formulas, and reactions and involves the mole concept and the balancing of chemical equations (Brown, LeMay, & Bursten, 2013). It involves the use of mathematical principles to determine the relationship between reactants and products in a given chemical reaction which is often represented as mass or volume and expressed in moles. Examples of problems that students could be faced with in stoichiometry activities are:

In a given reaction between zinc metal and hydrochloric acid to form zinc chloride and hydrogen gas molecule.

- i. Write a balanced chemical equation for the reaction.
- ii. How much ZnCl_2 (in grams) will be produced if 5g of zinc reacts with the acid?
- iii. How much in gram of hydrogen gas will be released?
- iv. Calculate the amount of HCl required to yield 12g of zinc?

A good mastery of stoichiometric concept is required to solve these problems. The students should be able to apply mathematical operations like ratio and proportion method.

The role of stoichiometry in the study of chemistry can never be over emphasized. Paideya (2010) and Opara (2014) described it as the heart of chemistry. Opara further asserted that stoichiometric principles are essential in engineering practices and in the design and manufacturing of materials and equipment. Etekoren, Inibehe, Ibemeji and Alamina (2019) opined that stoichiometry concepts have wide range of industrial applications. A good mastery of

stoichiometry problem solving skills is essential in solving problems in many chemistry topics including quantitative analysis, colligative properties, mass-volume relationship, mole concept, chemical equilibrium, gas laws etc. It is also essential in solving problems in practical chemistry particularly in volumetric analysis. It is the foundation of chemistry, so if students cannot understand stoichiometry, they cannot understand chemistry (Paideya, 2010). It has also been described as one of the most difficult concepts in the chemistry curriculum (Bridges, 2015; Kimberlin & Yeziarski, 2016). Studies show that students lack basic understanding of Stoichiometry concepts and so have resorted to algorithm in stoichiometric problem solving (Kusi, 2013). Hence innovative/students-centered strategies must be integrated in teaching them.

In Nigeria and other developing countries, many chemistry education researchers have identified that stoichiometry pose a lot of difficulties to students both at secondary schools and higher institutions. The same effect was also observed in the developed countries (Gulacar, Overton & Bowman, 2013). Bridges (2015) noted that students' understanding of this concept is low, with many students demonstrating surface learning only. The researcher further asserted that many students show indifferent attitudes in chemistry when the stoichiometry topics are introduced. This problem may have led to inconsistencies in students' achievement in chemistry as well as reduction of number of students offering chemistry courses at tertiary institutions over the years.

From the foregoing, the roles of stoichiometry in teaching and learning of chemistry has been highlighted. Evidence of stoichiometric difficulties also exists in literature as captured above. Hence it becomes imperative to explore these learning difficulties so as to proffer effective solutions.

Concept of Learning Difficulties

Learning Difficulties (LD) are conditions which inhibits an individual's ability to gain knowledge and skills at the same rate as his or her peers. It is a problem wherein an individual needs much effort to learn effectively, caused by the brain's inability to receive and process information (Akinoso, 2014). It is a classification which includes several disorders in which a person has difficulty in learning a particular concept in a typical manner or performing a particular task without the guidance of a peer or a



teacher (Wonu & Zalmon, 2017). Akinoso (2014) explained that it as a problem whereby an individual requires much work to successfully learn, as a result of the failure of the brain to receive and process information. Thus in a school setting, students with learning challenges might require extra opportunity to embrace ideas introduced by the teacher, the learning materials or to finish tasks.

Students with learning challenges may not learn similarly or as fast as their mates, and they could find specific aspect of their learning challenging, such as advancement of fundamental abilities, mathematical skills manipulations, ability to interpret abstract ideas etc. Akinoso (2014) identified the following causes of LD as follows; low quality of guidance, poor educational methodology, non-use of informative materials for guidance, poor nourishment and health problems.

In the context of stoichiometry, it is important that the exact causes of students' learning difficulties are known so as to design strategies to address them.

Causes of Students' Learning Difficulties in Stoichiometry

Many researches have been done to ascertain the causes of these learning difficulties in stoichiometry. One of the major causes of learning difficulties is students' poor mathematics skills. Adigwe (2013) and Opara (2014) noted that students' poor background in mathematics often affect them in solving problems in stoichiometry. Dahsah and Coll (2008) also highlighted that students' poor mathematics background has contributed to difficulties in stoichiometry.

Another reason why students encounter difficulties in stoichiometry is because of its abstractness (Mandina & Ochonogor, 2018). Stoichiometric concepts exist in sub-infinitesimal and emblematic degrees of representing chemical phenomena. The sub-infinitesimal degree involves undetectable particles which are real whereas the emblematic degrees of representing chemical phenomena is the chemical language expressed as symbols, formulae, equations, pictorial representations, graphs and mathematical representations (Sirhan, 2007). Stoichiometric terms such as the mole, volume, chemical formula, chemical equations, limiting reactants, and percentage yield are abstract and students often find it very difficult to connect these concepts to real world problems. Students' inability to visualize these concepts have

perhaps affected their rate of conception and retention of these concepts. Upahi and Olorundare (2012) noted students' inability to balance chemical equations. Chandrasegaran, Treagust, Waldrip and Chandrasegarian (2009) reported students' inability to recognize the limiting reagents in a chemical reaction. In one of the studies conducted in Thailand, many students thought that limiting reagent was the reactant present in excess (Dahsah & Coll, 2008). These problems stem from abstractness of these stoichiometric concepts. This is a huge problem.

Another source of learning difficulties that is worth mentioning is misconception. Evidence of students' misconception on stoichiometry and mole concepts exists in literature (Dahsah & Coll, 2008; Kimberlin & Yezierski, 2016; Gauchon & Meheut, 2017). Madina and Ochonogor (2018) also revealed that the sources of students' difficulties stem from the misconceptions students have regarding the concept of limiting reactants, balanced equations, stoichiometric ratios and confusions relating to subscript and coefficient, mole ratio among other sources. Because of the overwhelming benefits of stoichiometry, there is need to develop innovative strategies to decrease students' learning difficulties and hence improve the understanding of the concepts. To effectively do this, the identified learning difficulties amongst students must be reasonably resolved.

Strategies for Resolving Students' Learning Difficulties in Stoichiometry

Studies have shown that the conventional teaching method has not yielded the much needed positive effects in resolving the issues of learning difficulties in stoichiometry. In a bid to address this issue, chemistry education researchers swung into action to advance more progressive and learner-centered approaches to teach stoichiometry. Some of these strategies are: process oriented guided inquiry learning (POGIL), collaborative learning, problem solving and computer assisted instruction (CAI).

Process Oriented Guided Inquiry Learning (POGIL)

The process oriented guided inquiry learning (POGIL) has been considered as an effective learning strategy. Pedretti (2010) and Kaundjwa (2015) advocated for the adoption of Process Oriented Guided Inquiry Learning (POGIL) in learning chemical stoichiometry. POGIL is a strategy which depends on guided inquiry learning, in which students in little

gatherings get taken part in painstakingly planned learning materials that guide them to produce and build their knowledge (Moog & Spencer, 2008). It is an active learning/ student-centered approach which includes providing an environment where learners are effectively taken part in mastering a discipline and creating fundamental abilities by working in independent groups on guided inquiry exercises (Kuddjwa, 2015).

In a POGIL classroom or laboratory, students work in small teams with the teacher acting as a facilitator of the instruction. It consists of students working in small, self-managed teams on specially designed guided inquiry materials. These materials supply students with data or information to interpret, followed by guiding questions designed to lead them towards formulation of their own valid conclusions. It aims at developing science process skills in addition to mastering course content.

POGIL is a student centered approach to teaching and learning. It focuses on problem solving, collaborative group work and critical thinking. The teacher plays a role of facilitator of instruction. Kudjwa (2015) noted that Learners work with a teacher as a facilitator on how investigations will be carried out.

In the area of stoichiometry, separate studies by Pedretti (2010) and Kaudjwa (2015) showed that the implementation of POGIL improved students achievement in stoichiometry and mole calculations when compared to traditional lecture method.

Problem Solving Strategy.

Problem solving pedagogical strategy has been considered as an effective learning strategy. Etokeren, Ibemenji, and Alamina (2019) found out that the adoption of problem solving pedagogical strategies can facilitate meaningful learning of reaction stoichiometry.

Problem solving is the act of characterizing an issue; deciding the reason for the issue; distinguishing, focusing on and choosing options for an answer; and implementing the answer. In a problem solving technique, learners grasp ideas by dealing with the issues (Maheshwari, 2017). This helps the students to learn new information by dealing with the issues to be addressed. The students are expected to observe, understand, analyze, interpret, find solutions, and perform applications that lead to a overall understanding of the concept. This method develops science process skills. Problem solving is rooted in

cognitive and social development theories of learning. The duty of the teacher is to guide the students to complete their tasks. Pallavi (nd) highlighted some of the roles of the teacher as follows- give suggestions not answers, offer a problem solving heuristic, allow time for the students to struggle with the problem, choose problems that require time, provide a variety of problems, allow students time to practice a heuristic and strategies among others.

There are various models of problems solving based teaching strategies in chemistry. These models are very useful improving students' problem-solving abilities. A good example is the model developed by Ashmore, Frazer and Casey (1979) which involves the following stages: Characterizing the objective of the issue, choosing data from issue articulation, choosing data from the memory, thinking and error in calculation.

Other models include the dimensional analysis devised to solve problems in stoichiometry, and the proportion or algorithmic method which compares the given amounts to the unknown amount and set up a relation between these amounts.

Researchers found out that problem solving strategies improved students' achievement in stoichiometry when compared to the lecture method (Etokeren, Ibemenji & Alamina, 2019). Therefore, chemistry teachers should be encouraged to employ this strategy in teaching stoichiometry among other topics in chemistry.

Collaborative Learning

Collaborative learning strategies have been considered as an effective learning strategy. Opara (2014) advocated for the use of collaborative learning in teaching and learning of stoichiometry. It is an educational approach to teaching and learning that involves groups of learners working together to solve a problem, complete a task, or create a product. Chiu (2008) asserted that unlike individual learning, people engaged in collaborative learning leverage on one another's resources and skills (asking one another for information, evaluating one another's ideas, monitoring one another's work, etc.). Cooperative learning depends on the model that information can be made inside a populace where individuals effectively connect by sharing ideas and take on different roles.

Collaborative learning is rooted in social constructivism. Social constructivism is based on the work of Piaget, Vygotsky, Bartlette, Bruner, Rogoff and Gestalt psychologists who theorized that learners'

understanding is both individual and social process (Woolfolk & Margetts, 2013). Thus, collaborative learning is commonly illustrated when groups of students work together to search for understanding, meaning, or solutions or to create an artifact or product of their learning.

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 Opara (2014), collaborative learning enhances critical thinking in learners. Therefore, during the process of collaborative learning, there is information flow among the student as well as between students and the teacher which enables both the teachers and student to achieve a common goal.

The impact of collaborative approaches on learning is consistently positive. Though few studies exist on its impact in chemistry. In the area of stoichiometry, Opara (2014) showed that collaborative learning is more effective than the traditional learning method as there was significant difference in the mean achievement scores of students exposed to collaborative learning and those exposed to lecture method. Thus the use of this method in teaching stoichiometry will be successful in addressing the issue of students' learning difficulties in stoichiometric concept.

Computer Assisted Instruction.

Another strategy which could also be effective in learning stoichiometry is the computer Assisted instruction (CAI). Computer Assisted Instruction is the use of computer, application software and other ICT tools in presenting classroom instructions. Kumari (2018) defined Computer Assisted Instruction as a technique for guidance in which the computer is utilized to educate the learners and where the computer contains the program which is intended to instruct and test the learners until a favored degree of capability is achieved. It is an innovative teaching and learning approach whereby subjects to be educated are painstakingly arranged, composed, and modified in a computer which could be run simultaneously in a few computer discs (Safo, Ezenwa & Wurshishi, 2015). CAI packages could be played in either audio and (or) video software to enable students learn at their own pace and at their leisure periods. It is based on Mayer's cognitive theory of multimedia (2009) which emphasized that significant learning happens when

verbal and visual materials are connected to a known idea existing in a student's cognitive structure.

CAI provides inclusive education to all learners irrespective of their ages, background, sociological status, gender, abilities and disabilities. It is learner centered and provides activity-oriented science teaching. Mihindo, Wachanga and Anditi (2017) asserted that CAI can present numerous dynamic and complex ideas that are very hard to explain using words, equations or class experiment. Abdulahi, Yusuf and Mohammed (2019) noted that CAI supports constructivism, multiple intelligence and cooperative learning in education. It helps the students to learn abstract concepts with clear understanding in science subjects. (Kumari, 2018).

Several advantages of CAI have been noted in literature. It helps to solve problems of lack of instructional materials for teaching chemistry and change the students' perspective that chemistry concepts are abstract and difficult to understand (Ezinwa, 2019). It provides immediate feedback and enable students to learn on their own pace (Gana, 2013). Njoku and Eze-Odurukwe (2015) noted that computer animations enhance and sustains students' interest and motivation throughout the teaching process. Therefore, with the use of CAI, there is a switch from traditional teacher- centered learning to learner-centred learning. Though there is no research done on the use of CAI in learning of stoichiometry, there exist a handful of studies carried out in other chemistry topics where CAI successfully improved students' learning outcomes. For example, recent study by Njoku and Eze-Odurukwe (2015) showed that computer animation strategy was successful in resolving students' learning difficulties in nuclear chemistry. The implication of this is that this strategy could be effective in resolving students' learning difficulties in stoichiometry. This is because this aspect of chemistry shares great similarity with nuclear chemistry in terms of abstractness and mathematical nature of some aspects. CAI has also been shown to be very successful in improving students' achievement in the following chemistry topics: Chemical bonding (Okorie, 2015), Organic chemistry (Otienio, 2017), electrolysis (Mihindo, Wachanga & Anditi, 2017), writing and balancing chemical equations (Ezinwa, 2019) among others

Suggestion for Improvement

Based on the investigations done, the suggestions for improvement are:



1. Chemistry teachers should adopt student-centered approaches in learning stoichiometry.
2. More innovative strategies should be developed and utilized in learning stoichiometry. Such strategy is the computer animation strategy which is capable of reducing abstractions.
3. Series of trainings and retraining (e.g. Seminars, workshops) should be organized for teachers regularly on how to integrate innovative strategies in teaching chemistry.
4. Remedial instructions should be used in teaching stoichiometric concepts
5. The chemistry teachers should liaise with their mathematics counterparts at schools to improve students' mathematical skills. Improvement in mathematics skills will increase their chances of achieving high in stoichiometry and mole concepts.

Conclusion

The paper discussed the invaluable roles of stoichiometry in the school curriculum. It was shown that students need to be very proficient in stoichiometric calculations so as to solve problems in many chemistry topics. However, studies have continued to show that stoichiometry is one of those topics that pose learning difficulties to chemistry students at secondary schools and higher institutions. Such studies attributed students' consistent poor achievement to lack of problem solving skills in stoichiometry. This study researched on the causes as well as ways of resolving the issues of these learning difficulties. The causes of learning difficulties identified include- mathematical nature of stoichiometry, abstract nature of stoichiometric concepts, misconceptions and students' lack of problem solving skills. Few strategies were suggested to reduce the issue of these learning difficulties- adoption of student-centered approaches, development of more innovative strategies (such as the computer animation strategy), trainings and retraining of chemistry teachers, use of remedial instructions and partnership between the mathematics and chemistry teachers in the schools to improve students' mathematical skills.

References

- Abdullahi, B., Yusuf, L. A., & Mohammed, I. B. (2018). A study of the effects of computer assisted packages on the performance of senior secondary students in chemistry in Zaria Educational Zone, Kaduna State, Nigeria. *International Journal of Secondary Education*, 6(4), 59-65.
- Adigwe, J.C. (2013). Effects of Mathematical Reasoning Skills on Students' Achievement in chemical stoichiometry. *Review of Education institute of Education journal, University of Nigeria Nsukka*, 23(1), 1-22.
- Adigwe, J.C. (2013). Effects of Mathematical Reasoning Skills on Students' Achievement in chemical stoichiometry. *Review of Education institute of Education journal, University of Nigeria Nsukka*, 23(1), 1-22.
- Ajayi, O.V. & Ogbeba, J. (2017). Effect of Gender on Senior Secondary Chemistry Students' Achievement in Stoichiometry Using Hands-on Activities. *American Journal of Educational Research*, 5(8), 839-842.
- Akinsola, N. (2011). Education and Science, Technology. *Journal of Research in Science Teaching*, 10(2), 12-16.
- Ashmore, A. D, Frazer, M.J. & Casey, R. J. (1979) Problem solving network in Chemistry. *Chemistry Education*, 56(6):377-379.
- Brown, T., LeMay, H., & Bursten, B. (2013). *Chemistry: The central science* (12th ed.). Upper Saddle River, NJ: Prentice Hall.
- Bruffee, K. A. (2009). Conjoined intelligence: Reading, writing, talk. Unpublished
- Chandrasegaran, A. L., Treagust, D. F., Waldrup, B. G. & Chandrasegaran, A. (2009). Students' dilemmas in reaction stoichiometry problem solving: deducing the limiting reagent in chemical reactions. *Chemistry Education Research and Practice*, 10, 14-23
- Chiu, M. M. (2008). Flowing toward correct contributions during groups' mathematics problem solving Archived 2017-03-29 at the Wayback Machine: A statistical discourse analysis. *Journal of the Learning Sciences*, 17 (3), 415 - 463.
- Dahsah, C. and R.K. Coll, (2007). Thai grade 10 and 11 students conceptual understanding and ability to solve stoichiometric problems. *Research in Science and Technological Education*, 25(2): 227-241.
- Etokeren, Inibehe, S., & Alamina, J. I. (2019). Effect of Problem-solving Teaching Technique on Students' Stoichiometry Academic Performance in Senior Secondary School



- Chemistry in Nigeria. *Asian Journal of Advanced Research and Reports* 4(3), 1-11.
- 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.
- Ezinwa, U. S. (2019). Effect of three modes computer assisted Instructional packages on students' Interest and achievement in chemistry. (Unpublished PhD. Thesis), Department of Science Education University of Nigeria, Nsukka.
- 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
- Gauchon, L., & Méheut, M. (2007). Learning about stoichiometry: from students' preconceptions to the concept of limiting reactant. *Chemistry Education Research and Practice*, 8(4), 362-375.
- Gayeta, N.E. (2017). Flipped classroom as an alternative strategy for teaching stoichiometry. *Asia Pacific Journal of Multidisciplinary Research*, 5(4), 83-89.
- Gulacar, O., Overton, T. L., & Bowman, C. R. (2013). A closer look at the relationships between college students' cognitive abilities and problem solving in stoichiometry. *International Journal of Physics & Chemistry Education*, 5(2), 144-163.
- Haider, A.H. and C.A.K. Al Naqabi, (2008). Emirati high school student's understandings of stoichiometry and the influence of metacognition on their understanding. *Research in Science and Technological Education*, 26(2), 215-237.
- Hanson, D.M. (2006). Instructor's guide to process-oriented guided inquiry learning, Retrieved June 2013, from [http:// www.pogil.org](http://www.pogil.org).
- Igboanugo, B. I., Igboegwu, E., Attah, F. O., & Okonkwo, G. I. (2020). Efficacy of integrating information communication technology (ICT) in teaching method for effective chemistry curriculum delivery. *International Journal of Education (IJE)*, 2(1), 1-10.
- Kaundjwa, A. O. T. (2015). 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.
- Kimberlin, S. & Yeziarski, E. (2016). Effectiveness of Inquiry-Based Lessons Using Particulate Level Models to Develop High School Students' Understanding of Conceptual Stoichiometry. *Journal of Chemical Education*, 93, 1002-1009
- Kumari, M. (2018). Development and Effectiveness of Computer-Assisted Instruction (CAI) on the Academic Achievement in Mathematics for Class IX Students. *International Journal of Research in all Subjects in Multi Languages*, 6(2).
- Kusi, D., (2013). *Improving the performance of students in titrimetry through cooperative learning in senior high schools within Kumasi metropolitan area*. Winneba: University of Education, Winneba
- Maheshwari, V. K. (2017). The Problem –solving Method in Education. Retrieved from <http://www.vkmaheshwari.com/WP/?p=2375>
- Mihindo, W. J., Wachanga, S. W., & Anditi, Z. O. (2017). Effects of Computer-Based Simulations Teaching Approach on Students' Achievement in the Learning of Chemistry among Secondary School Students in Nakuru Sub County, Kenya. *Journal of education and practice*, 8(5), 65-75.
- Njoku, Z.C. & Ezeodurukwe, P. I. (2015). Resolving Nigerian Secondary school students' learning difficulties in Nuclear chemistry using computer animation solution. *Procedia – Social and behavioural Sciences*, 176(2015), 1034 - 1040.
- Ogembo, O. J. (2017). Effects of Computer Assisted Learning on Instruction in Organic Chemistry in Public Secondary Schools in Kwale County, Kenya (Doctoral dissertation), Kenyatta University.
- Okorie, E. U. (2014). Effects of instructional software package on students' achievement and interest in chemical bonding. (Unpublished phd. Thesis), Department of science education, university of Nigeria, Nsukka.
- Paideya, V. (2010). Exploring the use of supplemental instruction: Supporting deep understanding and higher-order thinking in chemistry. *South African Journal of Higher Education*, 24(5),



- 758-770. Retrieved from <http://www.sabinet.co>
- Pallavi (nd). Learner centred instructional techniques/methods. <https://www.patnauniversity.ac.in/e-content/education/Med76.pdf>
- Pedretti, L.A (2010). The effect of inquiry-based activity on attitudes and conceptual understanding of stoichiometry problem solving High school. *A researcher paper submitted for the requirement of Master of Science degree in education. University of Wisconsin* in stout. Retrieved from <http://www2.uwstout.edu/content/lib/thesis/2010/2010pedrettil>.
- Sirhan, G. (2007). Learning difficulties in chemistry: an overview. *Journal of Turkish science education*, 4(2)2- 20
- Wonu, N., & Zalmon, I. G. (2017). Diagnosis and remediation of senior secondary students' common learning difficulties in mathematics from chief examiners' report. *European Journal of Research and Reflection in Educational Sciences*, 5(1).
- Woolfolk, A. & Margetts, K. (2013). *Educational Psychology*. 3rd Ed NSW Pearson Australia. 95-100' 323