African Journal of Educational Studies in Mathematics and Sciences Vol. 13, 2017

# Using problem-solving instruction to overcome high school chemistry students' difficulties with stoichiometric problems

S. [1]Mandina & C. E. [2]Ochonogor.

## Abstract

The study sought to find out the difficulties encountered by high school chemistry students when solving stoichiometric problems. The study adopted a quasi-experimental design. 525participants drawn from 8 highs schools in a local education district in Zimbabwe participated in the study. A validate stoichiometry achievement test was used to collect data at pre-test and post-test stages. The researchers also prepared a difficulty identification index to analyse the difficulties encountered by the students. Quantitative data was analysed using descriptive statistics. From the findings, six major difficulties identified were lack of understanding of the mole concept, inability to balance chemical equations, use of inconsistent stoichiometric relationships, identifying the limiting reagent, determination of theoretical yields and identification of substances in excess. The study also found that the use of problem-solving instruction was effective in remedying the identified difficulties in comparison to the conventional lecture method. It was strongly recommended that chemistry educators should analyse and understand student difficulties if they are to assist the learner to become confident and efficient problem solvers. Furthermore chemistry educators should implement the problem-solving pedagogical technique as a means of addressing the difficulties students have in stoichiometry problem-solving.

Keywords: stoichiometry; difficulties; problem-solving; chemistry educators

## Introduction

The academic performance of students in any subject serves as an important indicator of the quality and effectiveness of teaching and learning which in turn can be used as an index to determine the extent to which educational objectives in the intended subject are being attained (Adesoji, Amilani & Dada, 2017). Chemistry, being the central science, derives its reputation as a difficult subject primarily from its dominant problem-solving nature. Furthermore, the subject being a physical science course involves problem solving (Ogunleye, 2009). Because of its complex nature and also that it is a conceptually difficult subject in the school curriculum, it becomes critically important for chemistry educators to be aware of the difficulties students encounter as they learn the subject so that appropriate measures can be taken to address these difficulties (Gegios, Salta & Koinis, 2017).

One of the key competences regarded as critical in science and chemistry education is the ability to solve chemical problems. An important areas in chemistry teaching and learning which possess a lot of challenges to students is stoichiometry problem solving (Kimberlin & Yezierski, 2016).

[1]Mandina, Shadreck works at Department of Applied Education, Midlands State University, Zimbabwe. Email: <smandinas@gmail.com>

[2]Ochonogor, Chukunoye Enunuwe works at Cape Peninsula University of Technology, Cape Town, South Africa. Email: enunuwechuks@gmail.com

Earlier studies by Sanger (2005) as well as Mulford (2002) have revealed the sources of these difficulties as caused by misconceptions students have regarding the concept of limiting reactants, balanced equations, stoichiometric ratios and confusions regarding subscripts and coefficients. Furthermore BouJaoude & Barakat (2000) consider stoichiometry as an abstract and difficult topic to teach as well as the teaching of stoichiometric calculations as challenging.

Other researchers such as Chandrasegaran et al (2009) highlight that the difficulties encountered by students during stoichiometry problem-solving can be attributed to a number of conceptual issues. Dahsah & Coll, (2008) also note that the limited proficiency of students in mathematics also contributes to the difficulties they encounter in stoichiometry problem solving. Studies by Fach et al (2007) have documented the overreliance of students on algorithms when performing stoichiometric calculations without making attempts to reason out their solutions. Such students as noted by Cracolice et al (2008) demonstrated their ability to use algorithms in solving traditional problems but lacking the conceptual understanding when faced with novel problems. Other researchers (Dahsah & Coll, 2007; Gauchon & Méheut, 2007; Chandrasegaran, et al., 2009) have identified students' inadequate understanding of the mole concept as a cause of their difficulties in stoichiometry.

From the foregoing discussion, it has been shown that students have difficulties in stoichiometry problem-solving as a result of lack of understanding of a number of concepts related to stoichiometry that influence their ability to solve stoichiometry problems. Thus, this research aims to examine the difficulties chemistry students encounter as they solve stoichiometry problems. Consequently, when chemistry educators understand the difficulties students experience when solving stoichiometric problems they will be able to design appropriate instructional strategies that can be implemented to address these difficulties thus assisting students to be conceptual problem solvers. In this study the use of problem-solving instruction based on Ashmore, Frazer & Casey (1979) as well as Selvaratnam-Frazer (1982) in remedying these difficulties will be investigated.

*Purpose of study and research questions*

The study investigated the difficulties encountered by chemistry students when solving stoichiometry problems. The following research questions guided the study:

1. What are the difficulties encountered by chemistry students when solving stoichiometric problems?
2. How effective is problem-solving instruction in overcoming these difficulties?

## Methodology

*Research design*

The study adopted the quasi-experimental research design in which two groups were involved. It employed a treatment group (intervention group) and a control group taught using the conventional lecture method. Both groups received instruction in stoichiometry from their teachers except that those teachers implementing the intervention had been trained on the use of the intervention in the teaching of stoichiometry. The teachers were trained for one week and implemented the intervention for two weeks in their classrooms. The entire study was completed in four weeks.

During the first week an achievement test in stoichiometry as was administered to the students as a pre-test and the student took one and half hours to complete the test. The subsequent two weeks were used to implement the intervention: the experimental group was taught using problem-solving instruction while the control group was taught using the conventional lecture method. After the implementation of the intervention (4th week) a stoichiometry achievement test was administered as post-test.

The sample of the study comprised of 525 Advanced level chemistry learners from 8 high schools in Gweru district, Zimbabwe. The sample was divided into two groups. The control group consisted of 275 learners while the experimental group consisted of 250 learners. The instrument for data collection was an achievement test in stoichiometry. The test consisted of both multiple choice and open ended items. The test was validated by experts in chemistry education. The data was analysed using descriptive statistics.

## Results and Discussion

*What are the difficulties encountered by chemistry students when solving stoichiometric problems?*

To identify the difficulties encountered by students when they are engaged in stoichiometric problem-solving, the researchers had to analyse the solutions given by students as they were answering open ended items during the pre-test. The responses of the participants were characterised by several difficulties as depicted in Table 1.

**Table 1 Analysis difficulties encountered chemistry students in a stoichiometry pre-test**

| | Percentage of students showing the difficulty | |
|---|---|---|
| Nature of difficulty | Experimental | Control |
| Understanding the mole concept | 61 | 66 |
| Balancing chemical equations | 47 | 45 |
| Use of inconsistent stoichiometric relationships | 78 | 78 |
| Identifying the limiting reagent | 88 | 88 |
| Determination of theoretical yields | 84 | 85 |
| Identification of substances in excess | 72 | 72 |

From Table 1, it will be seen that six difficulties were observed to be encountered by students during stoichiometric problem-solving.

*How effective is problem-solving instruction in overcoming these difficulties?*

To address this question a comparative analysis of problem-solving instruction and the conventional lecture method was done by comparing the number of students encountering difficulties before (at pre-test) and after the intervention (post-test). The data is shown in table 2 below.

**Table 2 Stoichiometry difficulties analysis to compare instructions at post-test**

| Nature of difficulty | Percentage of students showing the difficulty | |
|---|---|---|
| | **Experimental** | **Control** |
| Understanding the mole concept | 10 | 48 |
| Balancing chemical equations | **8** | **30** |
| Use of inconsistent stoichiometric relationships | 30 | 60 |
| Identifying the limiting reagent | **27** | **65** |
| Determination of theoretical yields | 25 | 64 |
| Identification of substances in excess | **18** | **58** |

Table 2 shows the number of students encountering the difficulties identified after the implementation of the intervention. Figure 1 depicts the graphical display of the data.

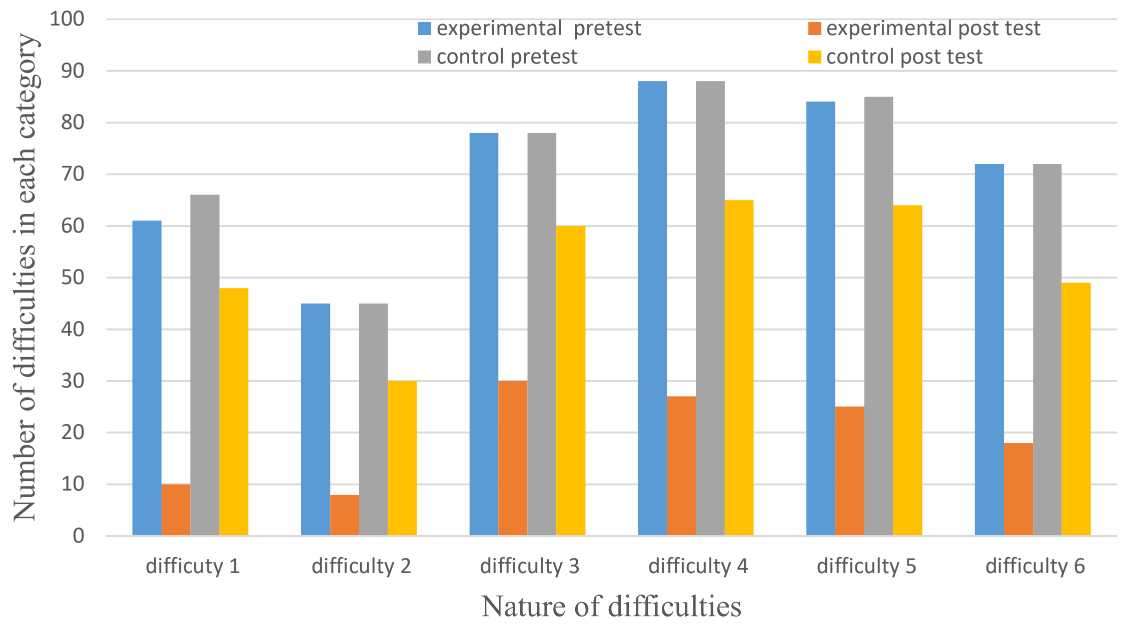


Figure 1 Students' difficulties in stoichiometry at pre-test and post-test stages

Figure 1 shows that the use of problem-solving instruction is more effective in remedying the difficulties students have in stoichiometry problem-solving than the conventional lecture method. Results show that problem-solving instruction generally manage to improve the problem-solving abilities of students as seen in the reduction of the number of student encountering the various difficulties at the post test stage. For instance, Figure 1 shows that problem-solving instruction reduced difficulty 1 from 61% at the pre-stage to 10% at the post-stage giving an effective rate of 83% in comparison to 27% in the conventional (control) conditions.

## Discussion

The finding of the study revealed that the types of difficulties encountered by chemistry students as they solve stoichiometric problems are lack of understanding of the mole concept, inability to balance chemical equations, use of inconsistent stoichiometric relationships, identifying the limiting reagent, determination of theoretical yields and identification of substances in excess. The findings are consistent with (Sheehan & Childs, 2009; Moss & Pabari 2010; Furio et al., 2002) who note that the mole concept as an important topic of which failure to understand the concept results in difficulties in understanding stoichiometry problems.

The findings are also in accord with Sanger (2005) and Nyachwaya et al. (2014) who have revealed that if students have difficulties in balancing chemical equations they will not be able to understand and solve stoichiometry problems properly. Furthermore, the findings show that learners have problems with the concept of the limiting reagent a misconception which hampers their success in stoichiometry problem-solving. This confirms earlier findings by Chandrasegaran, et al., (2009) aswell as Sostarecz & Sostarecz (2012) if students cannot identify the limiting reactant then they will have difficulties in determining theoretical as well as actual yields.

The results of the study further demonstrate the superiority of problem-solving instruction to the conventional lecturer method in successfully fostering their problem- solving performance of learners which is consistent with earlier studies in physical science, chemistry and biology problem solving learning respectively ( Cheng et al., 2017 ;She et al., 2012; Yu et al., 2010).

## Conclusion

The study has gathered evidence supporting the view that the recurrent difficulties encountered by high school chemistry students in solving stoichiometric problems results from lack of conceptual understanding of the basic stoichiometric concepts such as the mole concept, balancing chemical equations, deducing the limiting reagent. Consequently, chemistry educators should ensure that their students understand these concepts before the can solve quantitative numerical problems. Secondly, problem-solving instruction is more effective and superior to conventional lecture method in remedying student difficulties relating to stoichiometry problem-solving.

## Recommendations

Chemistry educators should analyse and understand student difficulties if they are to assist the learner to become confident and efficient problem solvers. Chemistry educators should implement the problem-solving pedagogical technique as a means of addressing the difficulties students have in stoichiometry problem-solving. Chemistry book writers and publishers should present content in a simple, logical and coherent manner so as to minimise the occurrence of student difficulties in stoichiometry.

## References

Adesoji , F.A., Omilani, N.A. & Dada, S.O. (2017). A Comparison of Perceived and Actual; Students' Learning Difficulties in Physical Chemistry, *International Journal of Brain and Cognitive Sciences*. 6(1), 1-8.

BouJaoude, S. & Barakat, H. (2000). Secondary school students' difficulties with stoichiometry. *School Science Review,* 81, 91-98.

Chandrasegaran, A. L., Treagust, D. F., Waldrip, 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.

Cheng, Shu-Chuan,. She, Hsiao-Ching. & Huang , Li-Yu. (2017). The Impact of Problem-Solving Instruction on Middle School Students' Physical Science Learning: Interplays of Knowledge, Reasoning, and Problem Solving. *Eurasia Journal of Mathematics, Science and Technology Education*. 14(3), 731–743

Cracolice, M. S., Deming, J. C., & Ehlell, B. (2008). Concept learning versus problem-solving: A cognitive difference. *Journal of Chemical Education*, 85(6), 873-878.

Dahsah, C. & Coll, R. K. (2007). Thai grade 10 and 11 students' conceptual understanding and problem-solving ability in stoichiometry. *Research in Science and Technology Education*, 25, 227-241.

Dahsah, C. & Coll, R. K. (2008). Thai grade 10 and 11 students' understanding of stoichiometry and related concepts. *International Journal of Science and Mathematics Education*, 6, 573 -600.

Fach M., de Boer T. and 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**, 13-31.

Furio, C., 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.

Gauchon, L., & Méheut, M. (2007) Learning about stoichiometry: from students" preconceptions to the concept of limiting reactant. *Chemical Education Research and Practice*, 8, 362-375.

Gegios, T., Salta, K & Koinis, S. (2017). Investigating high-school chemical kinetics: the Greek chemistry textbook and students' difficulties. ***Chemistry Education Research and Practice.*** 2017, **18**, 151-168

Kimberlin, S. & Yezierski, 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

Moss, K. & Pabari, A. (2010). The mole misunderstood. *New Directions*. 6, 77-86

Mulford, D.; Robinson, W. An inventory for alternate conceptions among first-semester general chemistry students. *Journal of Chemical Education.* 79 (6), 739−744.

Nyachwaya, J.M., Warfa, A.M., Roehrig, G.H. & Schneiderd, J.L. (2014). College chemistry students' use of memorized algorithms in chemical reactions. *Chemistry Education Research and Practice*, 15, 81—93.

Ogunleye, A.O. (2009). Teachers' and Students' Perceptions of Students' Problem-Solving Difficulties In Physics: Implications For Remediation. *Journal of College Teaching & Learning*. 6(7), 85-90

Sanger, M. (2005). Evaluating Students' Conceptual Understanding of Balanced Equations and Stoichiometric Ratios Using a Particulate Drawing. *Journal of Chemical Education*. 82 (1), 131−134.

She, H. C., Cheng, M. T., Li, T. W., Wang, C. Y., Chiu, H. T., Lee, P. Z., ... & Chuang, M. H. (2012). Web-based undergraduate chemistry problem-solving: The interplay of task performance, domain knowledge and websearching strategies. *Computers & Education*, 59(2), 750-761.

Sostarecz, M.C. & Sostarecz, A.G. (2012). A Conceptual Approach to Limiting-Reagent Problems. *Journal of Chemical Education 89* (9), pp 1148–1151

Yu, W. F., She, H. C., & Lee, Y. M. (2010). The effects of Web-based/non-Web-based problem-solving instruction and high/low achievement on students' problem-solving ability and biology achievement. *Innovations in Education and Teaching International*, 47(2), 187-199.