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AN INTERVENTION ON SUPPORTING TEACHERS' UNDERSTANDING OF AND MEDIATION OF LEARNING OF STOICHIOMETRY IN SELECTED SCHOOLS IN THE ZAMBEZI REGION

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ABSTRACT

The study investigated six Physical Science teachers from three different High schools within Katima Mulilo urban about their understanding of and mediation of learning of stoichiometry. All the Physical Science teachers teach Physical Science in Zambezi region and volunteered to be part of the research process, using participating action research (PAR) within community of practice (CoP). The participants answered questionnaires, interviewed on the mediation of learning of stoichiometry and took part in the intervention workshop. Sixty learners, twenty from each school answered stoichiometry diagnostic test and were taught during afternoon-school programme. The learners voluntarily agreed to be part of the research processes after consultation. The findings revealed that the use of a diagnostic test on learners made the Physical Science teachers aware of the learners' challenges in stoichiometry and what is difficult to understand, which necessitated the need for intervention workshops to assist them. It also helped in the use of prior knowledge, one of the tenets of topic specific pedagogical content knowledge (TSPCK) to access what learners already know about stoichiometry.

KEYWORDS: Stoichiometry, Mediation, diagnostic test, intervention-workshop.

INTRODUCTION

Stoichiometry is an important component of Chemistry. It deals with the quantitative relation between the numbers of moles, and therefore mass, of various products and reactants in a chemical reaction (Brown et al., 2014). These scholars define stoichiometry based on mass-mole, and in this regard, they understand stoichiometry as the quantitative aspect of the mass-mole number relationship, chemical formulas, and reactions and involve the mole concepts and the balancing of chemical equations. This definition of stoichiometry is also supported by Zumdahl (2014). Stoichiometry conceptual understanding aims to understand the concept of chemical reaction with other reacting materials and this is addressed in the Namibian Senior Secondary Certificate Ordinary/ Higher (NSSCO/H) curriculum. Addressing conceptual understanding in the stoichiometry curriculum is difficult for most learners.

In Chemistry, the concept of stoichiometry is considered the most complicated concept to master (Hand, Yang, & Bruxvoort, 2007). On account of stoichiometry dealing with abstract concepts, learners encounter challenges to learn the concepts.

Huddle and Pillay (1996), in their study conducted in South Africa, revealed that university students have misconceptions when solving limiting reagent questions in stoichiometry. Students assumed that the limiting reagent implied the substance with the smallest number of moles.

Furio, Azcona and Guisasolo (2002) in their study conducted in Spain, researched the practice of the learning and teaching of the concepts of amount of substance and moles, handling the amount of moles in stoichiometry calculations was a challenge. Similarly, BouJaoude and Barakat (2003) in their study about learners' problem-solving strategies in stoichiometry carried out with selected private schools in Lebanon. Results from the study confirmed that incorrect procedures were used for solving mole, volume, mass and molar quantities in stoichiometry. Furthermore, several misunderstandings were identified about limiting reagents, the mole concept and balancing of chemical equations (Sostarecz, & Sostarecz, 2012).

Opara (2014), in her research on the concept of stoichiometry in the Eastern part of Nigeria, used collaborative learning after she found that learners faced challenges with understanding stoichiometry. Hanson (2016), in an interpretive study about Ghanaian teacher trainees' conceptual understanding of chemical stoichiometry with a sample of 78 teacher trainees confirmed that stoichiometry learning was mostly done by using factor-label undefined strategies and algorithmic methods. The trainees were found to have persistent stoichiometry problems with conceptual interpretations due to the inability to translate word problems into mathematical equations. Hanson (2016) thus suggested that teachers should teach the mole concept and related terms until learners clearly understood them before engaging them in finding solutions to numerical problems.

In Namibia where the study was carried out, the challenges were also observed Kanime (2015). In an effort to find the solutions to the problems that learners encounter in stoichiometry, this study focused on an intervention on supporting teachers' understanding of and mediation of learning of stoichiometry. The study thus sought to address the following research question:

What are Grade 11 Physical Science teachers' understandings of teaching stoichiometry in the Zambezi Region of Namibia prior to the intervention?

Theoretical Framework

The theoretical framework informing this study was the theory of constructivism; namely, Piaget's cognitive constructivism and Vygotsky's social constructivism as well as Shulman's (1986) PCK. These theories are suitable for this study because teachers are within the same community, but teach in different schools. These teachers socially interact with each other to share knowledge (Vygotsky, 1978). The problems they solve deal with how they handle stoichiometry concept in classroom practices (Shulman, 1986).

Miles and Huberman (1994) hypothesize that a theoretical framework is important in the designing of a study as a visual or written product. To Grant and Osanloo (2014), a theoretical framework is the foundation which is used to construct knowledge in a research study. A theoretical framework is also regarded as a working model which allows the researcher to explore the relationships among variables in a logical and prescribed fashion.

Methodology, data gathering and analysis process

This study sought to explore an intervention to support teachers' understanding of and mediation of learning of stoichiometry in selected schools in the Zambezi Region of Namibia This study used an exploratory mixed method design, survey questionnaire (Creswell et al., 2016), Quantitative data were generated from diagnostic tests given to learners without coercing them.

Qualitative data were generated from workshop discussions, observations, interviews and reflections and it had greater weight compared to the quantitative.

This study was underpinned by an interpretive paradigm (Bertram & Christiansen, 2015; Cohen, Manion & Morrison, 2018).Creswell et al. (2016) state that interpretivists recognise the complexity of the world and acknowledge that reality can only be accessed through the social constructions such as language, consciousness and shared meanings. Within the interpretive paradigm, The interpretive paradigm is used to create a complete vision of how we interpret knowledge; how individuals see themselves in relation to knowledge and the methodological strategies we use to surface it. The interpretive paradigm therefore fits this study as the interpretivists purport to understand the meaning which informs human behaviour and to make “interpretations with the purpose of understanding human agency, behaviour, attitudes, beliefs and perceptions” (Bertram & Christiansen, 2015, p. 26).

Six Physical Science teachers and sixty grade 11 learners from three different secondary schools in the Zambezi region were purposely selected to participate in the study after consultation. Qualitative data were generated using stoichiometry topic specific pedagogical content knowledge (TSPCK) tool as questionnaire for teachers. This was followed by one-on-one semi-structured interviews to capture the Physical Science teachers’ experiences about mediation of learning of stoichiometry. The interview took about 30 minutes for each participant. A thematic approach to analyse and make sense of data was employed resulting in colour coding, categories and themes emerging in relation to the research question. TSPCK tenets were used as lenses in the data analysis process. Quantitative data were generated when the learners’ diagnostic achievement test were marked by the teachers and the researchers in order to establish learners’ prior knowledge, what they found difficult to understand and to answer the research question.

FINDINGS AND DISCUSSIONS

The findings of this study revealed that the use of a diagnostic test on learners made the Physical Science teachers aware of the learners’ challenges in stoichiometry. Learners encounter challenges to answer questions about the stoichiometry concepts, such as moles, limiting reagents, percentage composition, balancing of equation, empirical and molecular formula. This tally with what is difficult to understand (Mavhunga & Rollnick 2013). These necessitated the need of workshop interventions to assist teachers to improve learning and teaching of stoichiometry.

Diagnostic test on learners also helped in the use of prior knowledge, one of the tenets of TSPCK, to access what learners already know about stoichiometry.

The findings of this study revealed that TSPCK is a challenge to Physical Science teachers. Data collection was done by using questionnaires, interviews and document analysis. A stoichiometric topic specific pedagogical content knowledge tool developed by Malcolm (2015) obtained with permission was modified to fit the context of the study. Data from questionnaires was collected, edited, coded and summarised and then analysed using the Statistical Package for Social Sciences (SPSS). Descriptive statistics such as frequencies and percentages were employed to show the patterns revealed from the findings. The major findings that emerged were, insufficient facility distribution and accessibility in secondary schools, lack of qualified Chemistry teachers in schools and lack of adequate home support for the learners. The study provided that if there were enough learning facilities and qualified Chemistry teachers in secondary schools, it might influence the factors affecting learner attitudes towards the teaching of stoichiometry.

It emerged from this study that three teachers (T2, T5 and T6) failed to answer questions on conceptual teaching strategies, what makes a topic easy or difficult to understand and questions on the representation.

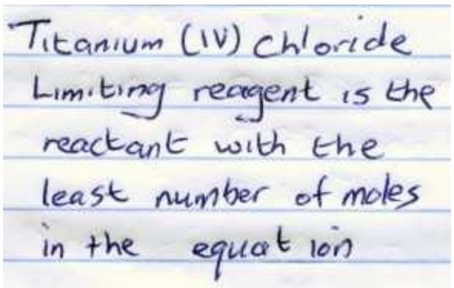
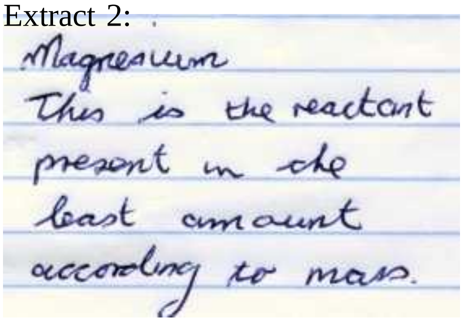
Below is the sample of questions on conceptual teaching strategies extracted from the questionnaire.

Learners are given the following question in the mid year examination.

> About 15% of the world's titanium reserves are found in South Africa. The titanium is a strong, lightweight corrosion resistant metal. It is used in the construction of rockets, aircrafts and jet engines. The titanium is prepared by the reaction of molten magnesium with titanium(IV)chloride at temperatures of approximately 1 000 °C. The reaction is represented by the equation below:
>
> $$TiCl_4(g) + 2Mg(\ell) \rightarrow Ti(s) + 2MgCl_2(\ell)$$
>
> In a certain industrial plant 3 540 kg of titanium chloride was reacted with 1 130 kg of magnesium to produce 894,24 kg of titanium.

Source: Department of Education (2007). Grade 11 Chemistry Paper, November Examination

The learners are asked to determine the limiting reagent of the reaction, giving reasons for their answers. The learners provide the following answers.

Extract 1:  Titanium (IV) Chloride Limiting reagent is the reactant with the least number of moles in the equation	Extract 2:  Magnesium This is the reactant present in the least amount according to mass.

Explain how you would assist these learners to move towards the correct answer, explaining what their errors are and highlighting the strategy you will use.

In your response:

(1) Explain why you think your strategy will work.

(2) Indicate what you consider as important in your strategy.

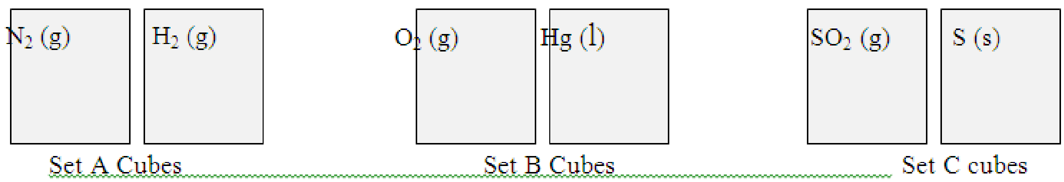
Figure 1: Excerpt on conceptual teaching strategies from questionnaire.

In my view, to encourage conceptual teaching strategies, what makes a topic easy or difficult to understand and representations is to present content in a context from which learners can derive meaning and the significance of chemistry in everyday situations, environmental issues and industrial processes (BouJaoude & Barakat, 2003). For example, stoichiometry could be taught within the context of practicals. This attests to the need for an intervention to assist teachers to improve their SMK and PCK. The intervention might enhance the development of the teachers in effective teaching of stoichiometry. Hasson (2016) also supports the idea of scaffolding teachers (intervention) in the mathematical component of stoichiometry, but scaffolding can go beyond mathematics to other concepts of stoichiometry. This can be extended to conceptual teaching strategies for effective understanding of stoichiometry teaching. These research findings seem to support the use of conceptual strategies for the effective teaching of stoichiometry concepts which is one of the tenets of TSPCK.

In contrast, only three teachers (T1, T3 and T4) answered the question in the questionnaire about learners' prior knowledge another tenets of TSPCK.

Before starting the section on reaction stoichiometry you give the learners a diagnostic test. One of the questions in the diagnostic test is reproduced below.

Each cube represents a volume of 22,4 dm^3 at STP. In which of the three pairs of cubes, Set A, Set B or Set C, is there 1 mole in each cube and in which of the three pairs cannot contain 1 mole in each cube?



How would you respond verbally to learners who state that all the cubes contain one mole?

Figure 2: Excerpt on learners' prior knowledge question.

One of the teachers, T1, further explained that: *"It's because response C all contains gases and any gas contains or occupies a volume of 22.4dm^3at STP. Each substance in response C has 1 mole and the components are in the same phase".*

From this excerpt, it seems T1 has adequate SMK of the stoichiometry concept since he was able to identify that the components are in the same plane. This confirms that SMK is necessary for effective teaching and delivery of stoichiometry concepts. This is in line with Kind's (2009) view that science teachers' PCK development and the relationship between PCK and SMK will help establish science teaching practice of consistently higher quality.

In addition, prior knowledge on moles and phases of substances might have assisted T1 in choosing the correct response. Prior knowledge provides an anchor to assimilate new knowledge into the cognitive structure (Taber, 2001). To some of the teachers, prior knowledge was very important because four out of six (67%) teachers got the answer correct.

T3 and T4 got the answers correct but gave no explanation to back up their chosen answers. For example, neglecting prior knowledge can result in learners learning things that are not in line with the concept being taught (Rochelle & Teasley 1995). Thus, the role of prior knowledge could be seen as the foundation of the learning and mediating processes, which enhance the understanding of concepts being taught (Fisher, 2007).

With regards to curricular saliency questions about stoichiometry from the questionnaire, T2, T3 and T4 responses are listed below,

What concepts in stoichiometry at Grade 11 do you believe are the main ideas for understanding by students at the end of the instruction of this stoichiometry topic?

Choose at least three concepts from the provided list and place them in a sequence that depicts the best order of teaching. Provide reasons for both your choice and suggested sequence.

T2 could not answer this section on curricular saliency. My assumption is that it could be possible that he does not understand what curricular saliency all is about. It could also be linked to BouJaoude and Barakat's (2003) assertion that sequencing of concepts might be difficult for some science teachers. It seems T2 might benefit from an intervention to improve the SMK and PCK of teachers' teaching of stoichiometry in the Zambezi region.

T3 was able to select only two concepts to be taught.

(1) Balanced chemical equations provide the combining ratios of reacting substances and their products in a chemical reaction; and

(2) *Reaction stoichiometry involves the determination of molar ratios of the number of reactants and products in a chemical reaction through balanced chemical equations.*

T3 further gave the reason for the choices made. These selected concepts set the basis for the law of conservation of matter. One can construe from this method of answering questions that curricular saliency was a challenge for T3. The two components listed by the teacher involved only balancing of chemical equations. This is aligned to BouJaoude and Barakat's (2003) view that sequence of chemistry subject matter still becomes debatable. For most of the concepts of chemistry it is difficult to determine the sequence. In my view, sequencing of stoichiometry concepts is a challenge because the concepts are interwoven and coming up with proper stoichiometry sequential concepts may need an intervention. This challenge would surely affect the teaching and learning of stoichiometry concepts, and an intervention might make a difference in the teaching and learning of stoichiometry.

T4's selection and order of teaching the concepts are arranged below.

(1) The mole is the SI unit for amount of substance and allows us to connect the macroscopic scale of matter with the microscopic scale of matter and can used to help count elementary particles that make up substances.

(2) Volume is the amount of space occupied by a sample and from the volume of a gaseous substance the amount of substance can be determined.

(3) *Concentration is a property of a solution and relates to the number of solute particles per unit volume.*

T4 further explained to justify his choice of selections saying that, "*When teaching concentration, learners should have a better understanding of moles and volume, since concentration is how many moles are present in a given volume of solvent*".

From the above selection, it is evident that T4 is experienced. This is line with Bridges (2015) who says that teachers should be knowledgeable, creative, and resourceful in their subject areas to help their students learn stoichiometry. The concepts selected were in sequence which could enhance the teaching and learning stoichiometry effectively; other teachers could learn from him as well.

To circumvent some of the challenges associated with the mediation of learning of stoichiometry the following recommendations were made.

CONCLUSION AND RECOMMENDATION

I analysed and discussed data from stoichiometry diagnostic test for learners and questionnaires for the Physical Science teachers. The findings revealed that the use of diagnostic test on learners made the Physical Science teachers aware of the learners challenges, hence the recommendation emanating from this findings are enumerated below.

- Teachers should engage in hands-on practical activities to put more emphasis on the concepts 'to be innovative' and 'to be critical', during classroom teaching of stoichiometry.
- The use of relevant teaching materials in the teaching and mediation of learning stoichiometry might be associated with a shift towards the use of TSPCK tenets for the teaching of stoichiometry concepts.
- I recommend that teachers develop Learning and teaching support materials (LTSMs) for any academic or non-academic classroom presentations for their continuing professional development (CPD) provided it enhances learning
- Teachers should develop effective teacher professional development activities such as study teams, cluster teaching, and peer coaching where teachers are expected to examine their assumptions and practices continuously

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