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Intervention workshop supportfor Physical Science teachers in developing exemplary lessons and learning and teaching support materials for teaching stoichiometry

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ABSTRACT: *The study investigated six Physical Science teachers from three different High school within Katima Mulilo community about their understanding of and mediation of learning of stoichiometry. All Physical Science teachers teach Physical Science in Zambezi region and volunteered to be part of research process, using participating action research (PAR) within community of practice (CoP). The participants were involved in intervention workshops on the mediation of learning of stoichiometry.*
The findings of this study further indicated that the community of practice (CoP) members acquired the professional transformations which were important breakthroughs in their careers. Transformation is defined in the Vygotskian framework as those forms of behaviour that are used between people in concrete social interactions (i.e. intermental plane to the forms of individual mental processes i.e. the intramental plane (Eun, 2008). The internalisation process does not occur automatically from a direct transformation of the intermental plane to the intramental plane, but through the use of mediators. The intervention workshops in my study were framed with activities serving as material mediators (artefacts) that aimed to solve stoichiometric problems. So, the collaborative working together of CoP members might lead to their continuing professional development.
KEYWORDS: *Stoichiometry, Mediation, material mediator, intermental plane, intramental plane intervention-workshop, PAR and CoP.*

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I. BACKGROUND AND PURPOSE OF THE STUDY

The focus of this study is on the workshop intervention practices for professional development for the Physical Science teachers. This study further explores how the Physical Science teachers developed and constructed new knowledge about stoichiometry for effective classroom teaching. The study also shows the need for a continuing professional development program for the participating teachers, and it benefited the teachers as such. Ladson-Billings and Gomez (2001) view professional development as the cornerstone of school reform aimed at raising academic performance. They argue that no amount of "standards, benchmarks, and high stake testing can bring about school improvement without giving attention to teacher quality" (p. 680). A study of the current status of CPD program implementation and its trials in government secondary schools of Dire Dawa in Ethiopia (Tisasu, 2014), shows that teachers have a positive attitude towards the CPD. Collaborative engagement, strategies of planning and execution of topic concepts might have encouraged teachers to develop positive attitude towards CPD. The CPD engagement differs from country to country.

Statement of the problem

DNEA yearly examiners' reports (Namibia. Ministry of Education, 2000-2015) indicate that conceptual understanding in Stoichiometry is generally poor. This problem might be due to the following factors:

- Not enough teaching materials in schools
- Inexperience with experiments associated with Physical Science concepts
- Lack of confidence in teaching the subject content knowledge in some areas of Physical Science
- Overcrowded science classrooms
- Absenteeism on the part of learners
- Learners not doing their homework.
- teachers' inadequate subject matter knowledge
- poor pedagogical content knowledge, and

- Lack of basic mathematics skills on the part of learners and science teachers, in topics such as ratio, percentages and proportions (Namibia. Ministry of Education, 2000-2015).

Significance of the study

This study addressed an intervention in form of workshops to support Physical Science teachers in developing exemplary lessons for teaching stoichiometry. In the four workshops conducted, various topics were addressed that helped teachers improve their subject matter knowledge (SMK) and pedagogical content knowledge (PCK). These workshop interventions equipped the teachers so that they teach Stoichiometry effectively. The study was necessitated by factors that contribute to the poor performance in Stoichiometry.It might also empower the teachers to develop the learners' scientific concepts involved in stoichiometry; this might in turn help more learners to understand stoichiometry and encourage them to major in Science and Technology at a tertiary institution of their choice. The study might also assist the Namibian Ministry of Education's policy of teachers' placement and improve the skills, learning and teaching capabilities of all the participants including the researcher. Finally, being a lecturer at the university, this study might also help to improve my own practice and ensure that the student teachers studying at the university are competent to teach the topic of stoichiometry.

II. THEORETICAL FRAMEWORK

Molasso (2006, p. 7), explains that "a theoretical framework refers to the theory that a researcher chooses to guide him/her in his/her research. Thus, a theoretical framework provides direct, practical, and interesting explanations and examples to answer a particular research problem". 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 exemplary allows the researcher to explore the relationships among variables in a logical and prescribed fashion.

Merriam (2009) explains that a theoretical framework is the structure on which research is based. Additionally, a theoretical framework is the vehicle driving all aspects of the research including the research problem, methodology, data analysis and interpretation of the data collected. Miles and Huberman (1994) hypothesise that a theoretical framework is important in the designing of a study as a visual or written product. Thus, the theoretical frameworks informing this study will be the community of practice (CoP), constructivism, namely, Piaget's cognitive constructivism and Vygotsky's social constructivism, and Shulman's pedagogical content knowledge (PCK) as discussed below.

Research goal

The main goal of the study would be to co-develop exemplary lessons, worksheets, as well as learning and teaching support materials (LTSMs). Thus the study sought to address the following research objectives:

- Explore subject matter knowledge (SMK) and PCK;
- Enhance research skills and
- Collaboration among thecommunity of practice (CoP) members even beyond the study,with the aim of improving the teaching and learning of stoichiometry.

I also recognised that improvement could only be achieved by active participation (Sedláček& Sedova, 2017) and commitment of all the Physical Science teachers within the community of practice. In the Zambezi Region where the research was conducted, 14 Physical Science teachers completed the questionnaires, but on my supervisor's advice only six Physical Science teachers I worked with participated in the study.

Research Design

According to Polict, Beck and Hungler (2001), a research design is a "researcher's overall strategy for answering the research questions or testing the research hypothesis" (p. 167). Research design incorporates samples, participants, method of data gathering, research instruments and implementation procedures of the instruments, data analysis and paradigm.

This study was underpinned by an interpretive paradigm (Cohen, Manion & Morrison, 2011; Bertram & Christiansen, 2015). Mertens (1998) opines that the basic assumption guiding the interpretive paradigm is that knowledge is socially constructed by people active in the research process. The interpretive paradigm aligns well with the CPD to be engaged in this study. This might be the case with Physical Science teachers, the subject adviser and researcher as they would collaboratively co-plan and implement the tenets of stoichiometry. The new knowledge might be developed by the collaborative effort of all the participants within ourcommunity of practice (CoP). Vygotsky (1978) posits that effective learning lies in the nature of social interaction between individual and their peers.

Selection of Participants

For the study, the professional development intervention involve a sample of six Physical Science teachers selected from three schools in the Zambezi Region.There were about 60 volunteered grade 11 participating learners(20 per school), who weretaught by these teachers using 'afterschool science enrichment approach' (Agunbiade, 2015).

Method of data generations

Creswell et al. (2016) argue that methods are the tools that researchers use to collect data. The tools enable researchers to gather data about social reality from individuals, groups, and texts in any medium. This study made use of the following data gathering tools: workshop discussions with reflective notes with teachers, and lesson observations as well as research journal done by some of the participating teachers, and me. As emphasized by Cohen, Manion, and. Morrison, (2011), the use of a variety of data generating techniques afforded me an opportunity to triangulate the data. Also as a researcher, keeping the research question in mind was of paramount importance because more than one method gave valuable data. Below is a table that summarises data generating methods used for this study.

Table 1: Data generation methods

Method/instruments	Purpose	Actors
Workshop discussions	Working together collaboratively to develop LTSMs and to construct knowledge	Six physical science teachers plus the researcher.
Videotaped lesson observations	To test the LTSMs for the teaching of stoichiometry. To critique the teaching methods through collaborative efforts.	3 physical science teachers from the 3 schools and the Researcher.
Research journal	Recording experiences and challenges during the research journey.	All research participants

Activities and results of the study
Intervention Workshop 1

The participating teachers shared their experiences about the teaching of stoichiometry in their schools. During the intervention workshopsome difficult stoichiometry concepts were identified, these were in line with the findings of Furio, et al., (2002). The identified difficult stoichiometry concepts concurred with the results of the diagnostic achievement test questions answered by the learners.

The difficult stoichiometry problems were harmonized with some other researchers who came up with ideas about the stoichiometry concept difficulties, listed below.

- **Limiting and excess reagent. (**Gauchon and Méheut,(2007)
- **Calculations of moles(**BouJaoude, & Barakat, (2003).**C**handrasegaran, et al., 2009)
- **Concentration formula to calculate moles in solution** (BouJaoude and Barakat, 2000)
- **Ratio calculationof moles in Stoichiometry**(Dahsah and Coll, 2008)
- **Empirical andMolecular formula calculations** (BouJaoude and Barakat, 2000)
- **Percentage composition**(Gilbert, 1998)
- **STPStandard Temperature and Pressure**
- **Balancing of equation (**Tóth and Kiss, 2005)
- **Actual yield and Theoretical yield.** (Hanson, 2016)

We carried out an experiment as community of practice (CoP) members to respond to a question raised by one of the teachers on limiting and excess reagent. Below is the experiment:

Materials: Candles, Beakers, matches, flat table or flat object, air (within laboratory)
Step 1: Two burning candles were setup and lit as seen in Figure 6.2, having enough supply of wax and air (Oxygen).
Step 2: One of the two burning candles was covered with beaker (Figure 6.3). Air access controlled.
Observations: The burning candle covered with beaker went off. Why?

Figure 1: Both candles where burning, having supply of air and fuel (nothing was limiting the combustion).

Figure 2: One of the burning candles was covered with Beaker, limiting the access of air to the burning candle.

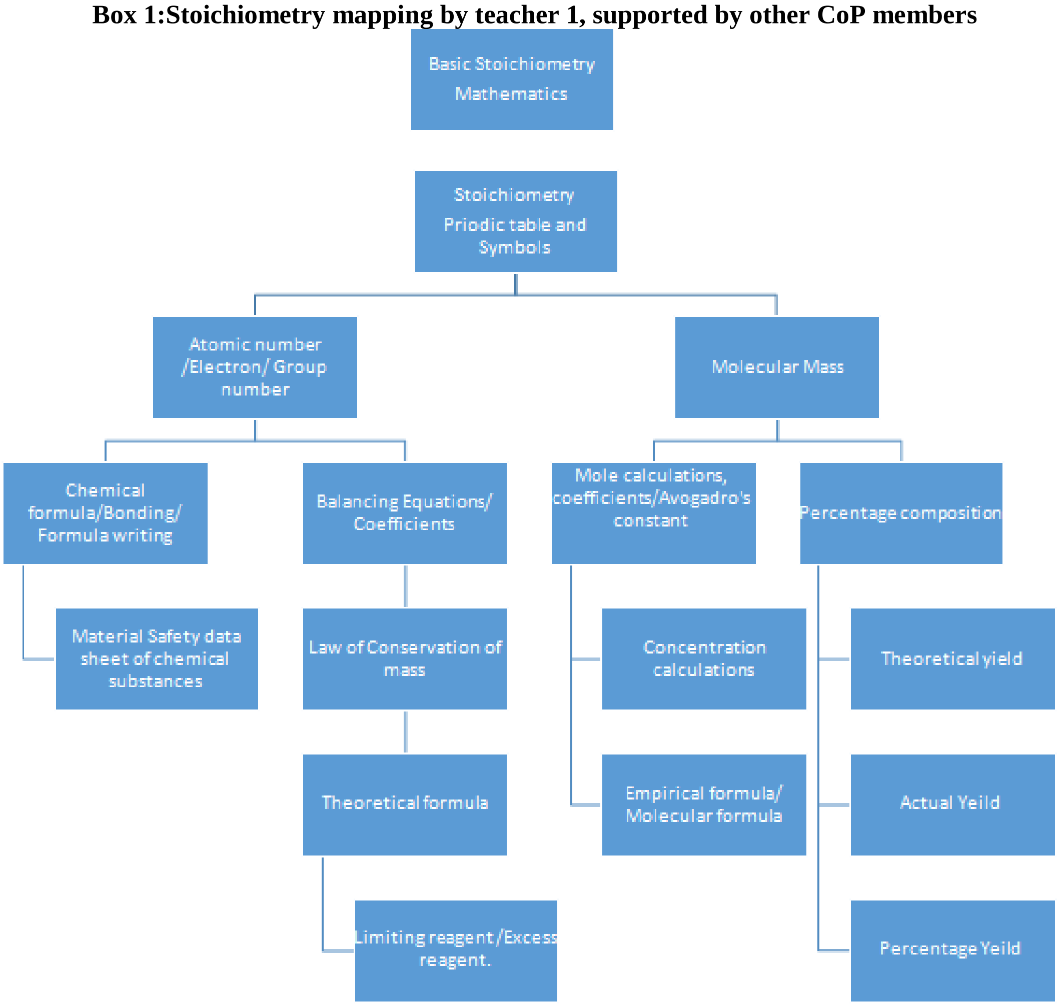
III. CONCLUSION:

There is limited supply of air to the burning candle and it went off**.**The experiment showed that a limiting reagent is the substance that finishes first when carrying out experiments involving chemical reactions.
In Figure 2, where one of the burning candles was covered, a beaker limited the air (oxygen) access to the wax in the burning candle and it went off. The other candle continued burning because nothing limits the supply of air.

Intervention Workshop 2

The second workshop was on Stoichiometry mapping and basic Mathematics. Stoichiometry mapping shows which concept comes before the other for coherence and curriculum saliency on stoichiometry for effective teaching in the classroom.The first mapping concept is basic mathematics (see Box 1). This was discussed by T1 and we agreed that Physical Science teachers can liaise with Mathematics teachers for unclear stoichiometry mathematics concept before teaching learners. This was in agreement with Croteau, Fox, and Varazo(2007) that in the beginning of teaching chemistry learners are taught variety of mathematics involving balancing of equations. The teaching of basic mathematics by either the mathematics teacher or by the Physical Science teacher enhances the understanding and teaching of stoichiometry.

Box 1:Stoichiometry mapping by teacher 1, supported by other CoP members



Below is the lesson plan or guide prepared by teacher 1, and basic Mathematics operations needed for the teaching of Stoichiometry.

Box 2: Basic Mathematics lesson plan

BASIC MATHEMATICS OPERATION 1

Objective: To teach the **basic** mathematics operations for real numbers on addition, subtraction,
Multiplication, and division to learners

Introduction:

The four ***basic mathematical operations***--addition, subtraction, multiplication, and division--have application even in the most ***mathematical*** theories. Thus, mastering them is one of the keys to enhance the understanding of ***mathematics*** that can be applied in the teaching of Stoichiometry in chemistry.

Basic Mathematics (operational) for stoichiometry

The purpose of this Basic Mathematics is to review basic mathematics operational concepts so that learners will be able to enhance the learning of stoichiometry. This will be fundamental to better prepare the learners for the stoichiometry concepts.

Step 1: Introduce the Basic Mathematics to learners by reviewing the material and working through problems.

Step 2: Mention the Basic Mathematics Refresher concepts (I) Fractions and Decimals, (II) Percentages (III) Order of Arithmetic Operations; (lV) Basic Algebra

Step 3: Content to be covered.

<u>Fractions and Decimals</u>

Fractions, decimals and percentages are all numbers that represent a part of the whole. We often
need to convert from fractions to decimals or from decimals to fractions.

Example:

Fraction Decimal

$$\frac{12}{40} = 0.3$$

<u>Converting a fraction to a decimal</u>

Divide the **numerator** (the top number) by the **denominator** (the bottom number) using your
Calculator.

This fraction is necessary when calculating the number of moles (n) in a given sample, molarity or concentration of samples.

Numerator is the mass of a given sample.

Denominator is the molar mass of the given sample as obtained from periodic table of elements.

BASIC MATHEMATICS OPERATION 2

Example: Using fraction to solve Stoichiometry questions.

Question 1: Find the number of moles of 12g of Calcium metals

12g is the mass of Calcium (Numerator)

40g is the Molar mass of Calcium as obtained from periodic table of elements (Denominator).

$$\frac{12}{40} = 0.3$$ **Moles or 0.3mols.**

Note that the final decimal in this example is expressed to one decimal place. Final decimals can be expressed to two or three places.

Rounding up or down of decimal numbers

Decimal numbers can be rounded up, when the number following is 5, 6, 7, 8, or 9.

$$\frac{6}{7} = 0.857142857$$

I. To round up to two decimal places, the answer is 0.86
II. To round up to three decimal places, the answer is 0.867

When you round off a decimal, you round upwards if the number following ranges from 5 to 9 (as seen in I above), and you round downwards or same, if the number following ranges from 0 to 4 (as in II above).

Converting a decimal to a percent

When converting a decimal to a percentage move the decimal point two places to the right. This is basically multiplying the decimal by 100.

Box 3: Basic Mathematics Operation in stoichiometry calculations.

Below isthe lesson plan prepared by teacher 2 on calculation of moles.

Topic: Mole Conversion

The mole is the central unit for converting the amount of a substance from one type of measurement to another. The number of moles of a substance can be calculated once the mass of the substance is known. Knowing the number of moles allows for a direct conversion to the number of particles. Two conversion factors are thus needed to convert mass to number of particles. The mole is also used to convert between the number of particles of a gas and the volume of a gas at STP. This molar volume of the gas is identical for all gases and has the value of 22.4 L/mol. The moles can be expressed in terms of the Avogadro's number [**6.02×10^{23}**]

Learning Objectives: Learners should be able to:

1. Convert among the number of particles, moles, and mass of a substance; and
2. Define molar volume and use it to solve problems.

Key words: Molar mass, Relative atomic mass, Atomic mass, Molar volume

LTSMs: Mole Conversions worksheet, Mass ↔ Moles, Moles ↔ Particles

Procedures: Discuss how to make the following conversions, using the line method:

- Mass ↔ Moles
- Moles ↔ Particles
- Mass ↔ Particles

Explain the concept of Molar mass, Relative atomic mass, Atomic mass, Molar volume, Avogadro's constant.

- Molar volume, volume of one mole of gas at STP = 22.4 L/mol. 1 mol of a substance = 6.02×10^{23}
    - Standard Temperature and Pressure (STP) = 0°C or 273K, 1 atmospheric pressure

Work some samples of stoichiometry questions for learners in the classroom and allow learners to practice

Conclusion: Summarise concepts taught and give Mole Conversions worksheets as assignment to learners.

1. How many atoms are in 0.62 moles of Ag?
2. How many moles of $BaNO_3$ contain 102.3 g?
3. How many atoms are in 56.3 g of copper?
4. A room with a volume of 3500 L contains how many moles of air at STP?
5. A glass of milk contains 5 g calcium. How many atoms of calcium is that?
6. If you burned 4.0×10^{24} molecules of natural gas (methane CH_4), what mass of methane did you burn?

Box 4: The lesson plan on calculation of moles prepared by T2

Box 5: Some highlights on calculation of moles by T2

Teacher 2 explained the Mole concept by defining the mole concept explicitly as seen in Box 5using the lesson plan in Box 4. Representation was used to make the mole concept very easy to understand. He supported the teaching with representation for other Physical Science to visualise the meaning of moles (Evagorou, Erduran, & Mäntylä, 2015). From theserepresentations a game was developed by the Physical Science teacher for others to play. T2 further explained that learners might learn better and improve their skills and understanding when they practice all types of stoichiometry games. Wright, Betteridge and Buckby (2005) mention that games provide a context for meaningful scientific communication, which takes place as the learners seek to understand how to play and communicate through the game. By playing games, learners are offered a practice as conventional drill exercises, but in a more meaningful way to improve their stoichiometry concepts. By doing so, learners might be immersed in using the stoichiometry language concepts, which could assist them to better internalise a newly constructed stoichiometry concept as reiterated by Vygotsky (1978).

Moles triangular game

How to play the moles triangular game:

1. Have a periodic table at hand;
2. Have the masses or moles of substance at hand or develop yours;
3. Two out of the components of triangular stoichiometry mole house must be known;
4. The game is played by three people with calculators in their hands;
5. 1st player chooses mass number e.g. 12 g;
6. 2nd player chooses mole e.g. 0.2 moles;

7. 3rd player tells you what to do and gives points to the first person to give the correct answer, 2 points for correct answer and 0 for wrong answer; and
8. Approximate the answer obtained to the nearest ten.

The constructed triangle Figure 3 houses all the tenets of moles calculating components.

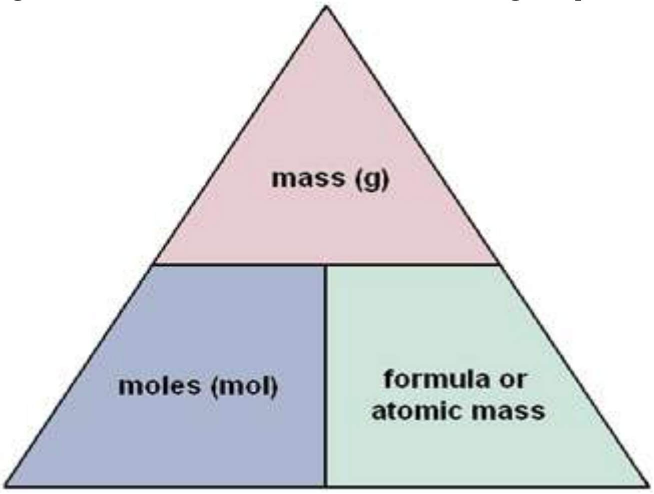


Figure 3: Formula triangle for calculating moles

The formula triangle representation can be used to explain the concept of moles, concentration and volume in solutions. This representation in the teaching of stoichiometry was very helpful, and it was seen during the time learners answered the diagnostic achievement test questions. It could be inferred that using representations during the teaching of stoichiometry enhances effective teaching and learning of stoichiometry.

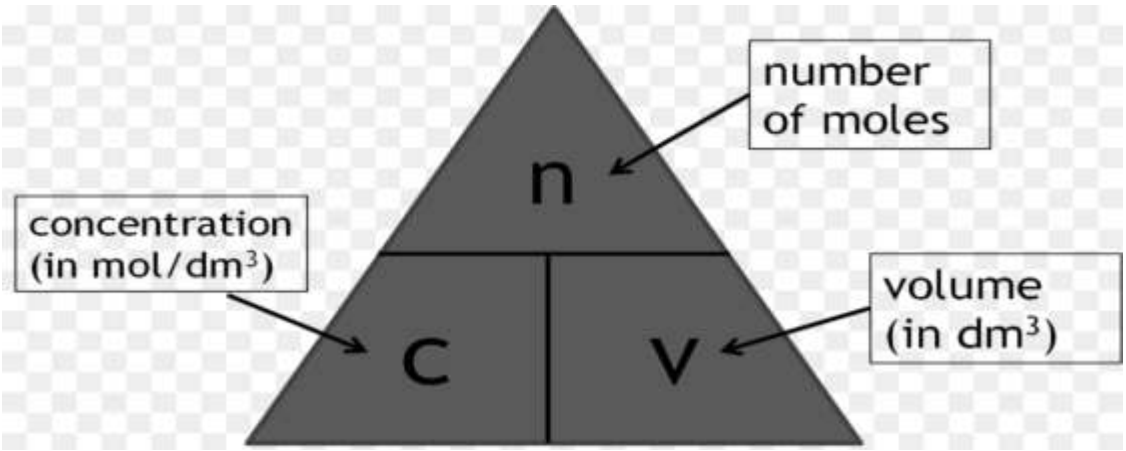


Figure 4: Formula triangle for calculating concentration in solutions

The game that was played to explain moles calculations was very interesting. After playing the game, the use of analogies became popular among the teachers. As a result, all the teachers were actively engaged in playing it during the second activity. Examples of moles calculations were carried out using the game analogue.

Workshop 3, learning and teaching support materials (LTSMs)

This activity was as per request by teacher 5 who asked that the CoP members be taught how to make learning and teaching support materials (LTSMs).I facilitated how LTSMs are developed.

Development of learning and teaching support materials

From this workshop 3, it emerged that most teachers had problems with the development of teaching and learning materials. This was an opportunity to engage the CoP members on how to go about developing teaching materials.Bušljeta (2013) accentuates that the purpose and role of teaching and learning resources does not only consist of making the educational process more attractive and interesting, but also of encouraging active learning and the development of different skills for the learners.The CPD of Physical Science teachers is strengthened as they learn how to make LTSMs for the teaching of stoichiometry.

Procedures of LTSMs making during the workshop

As agreed before, I discussed with the community of practice (CoP) members how to make LTSMs. I quickly prepared a lesson plan on the methods of preparing LTSMs using available materials. The lesson was on how to make the electronic structure of an element.

Box 6: Some highlights on exemplary lesson plan of electronic structure of element

Step 1 - Gather Information on the element to develop

Before you can build your LTSM, you will need to know how many **protons,neutrons and electrons** your element has. Obtain this from the Periodic Table of Elements.

Step 2 – Materials to use

Cardboard, Bottle tops, threads, seeds, (any appealing available materials of your choices). Colour or paints, glue and ball pens

Step 3 - Build the Nucleus

Show that the nucleus, the central part of the atom is made from protons and neutrons. Define the protons and neutrons.

Step 4 - Placing the Electrons on the orbit.

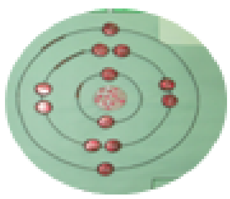
The electrons are found outside the nucleus on the orbit, place electrons there.

Step 5 – Exemplary explanation

Anexemplary is a simplified representation of an object or element.

Step 6: Construct your own exemplary (model) now, pick an element of your choice

The Bohr Exemplary



Below is LTSM of the electronic structure of Magnesium constructed by the participating community of practice (CoP) members during the workshop

Figure 5: LTSM **of the electronic structure of Magnesium constructed by CoP members group**

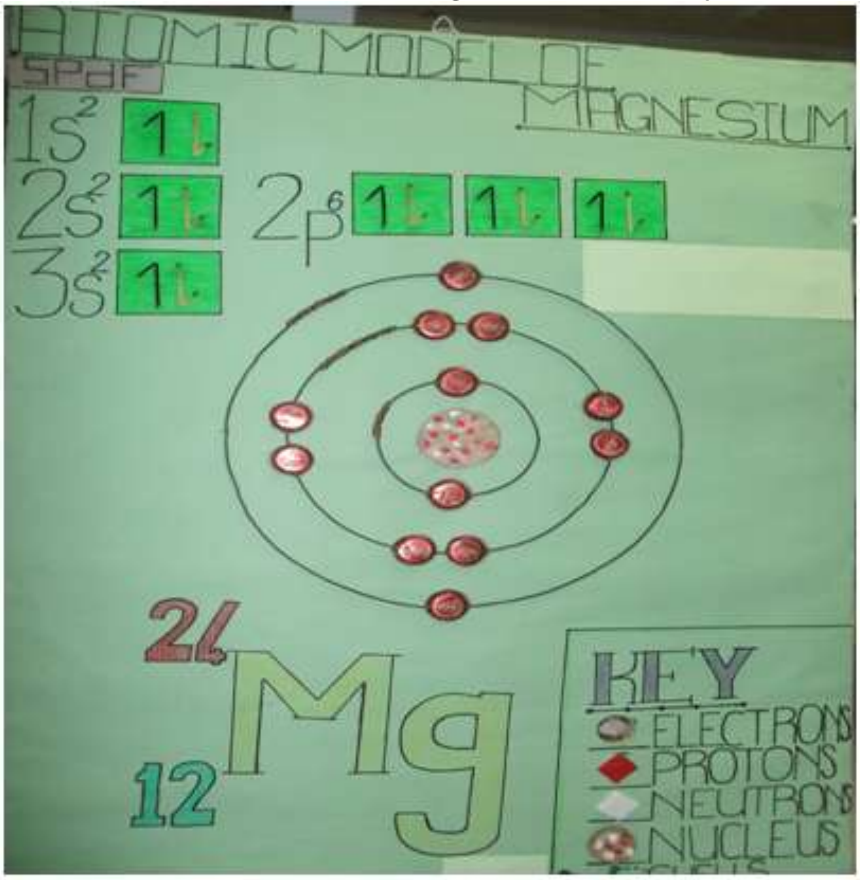
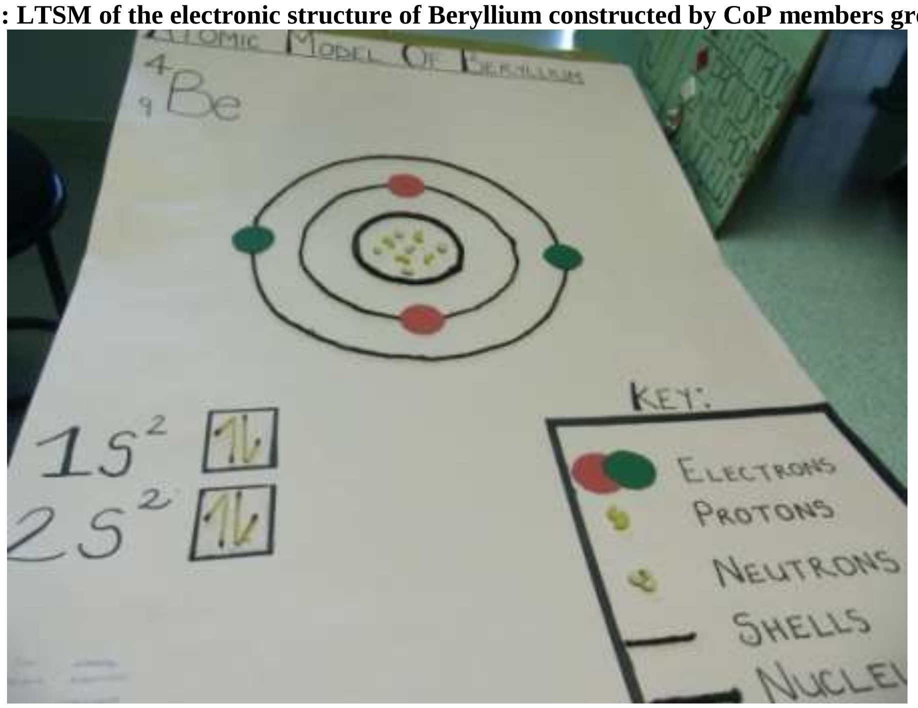


Figure 6: LTSM of the electronic structure of Beryllium constructed by CoP members group 2



Reflections on the LTSMof electronic configuration construction

The Physical Science teachers enjoyed working together. When the construction of the electronic configuration started, T2 asked questions about the use of local materials. I said that it is central to analogues discussed, that locally available materials (Asheela, 2017) for the teaching or constructing LTSM be used. During the discussion I made reference to the materials used when constructing the electronic configuration. For example, the matchsticks were used to show a pair of electrons in the orbit, coloured papers to beautify the LTSM and cardboard to house the electronic configuration. Bottle tops were used to show the position of electrons within the shell, marker pens were used for drawing, threads for making shells and seeds (to show the protons and neutrons).

Workshop 4

Workshop 4 was on percentage composition of substances and was presented by teacher 5.Below is the lesson plan prepared by T5 on percentage composition. T5 made use of an analogy representation in teaching the percentage composition.

Box 7: Highlights on practical analogue on percentage composition procedures

Objective

To become familiar with the methods of calculating percentage composition of a substance or mixture.

Apparatus and Chemicals

Chemical balance, Bunsen burner, heat, Beakers, evaporating dish

Unknown mixture of iodine and Silicon dioxide

Discussion: Stoichiometry mixture's calculation

The mixture that you will separate contains two components: NH_4C1, and SiO_2. Their separation will be accomplished by heating the mixture to sublime the: NH_4C1 from SiO_2

Procedures:

Step 1: Carefully weigh a clean, dry evaporating dish.

Step 2: Then put the unknown mixture in the evaporating dish.

Step 3: Weigh the evaporating dish containing the sample and calculate the sample weight.

Step 4: Place the evaporating dish containing the mixture on a hot plate under the fume cupboard.

Step 5: Heat the evaporating dish until brown fumes are no longer formed. Heat carefully to avoid spattering and stir.

Step 6: Allow the evaporating dish to cool until it reaches room temperature and then weigh the evaporating dish with the contained solid. The loss in weight represents the amount of Iodine in your mixture.

Calculate the % composition of I2 (Iodine) = $\frac{\text{Mass of component in grams alone X}}{\text{Mass of sample in grams}}$ 100

= % component of iodine

The analogy practical seemed to be an eye-opener on the teaching of stoichiometry. One of the teachers (T4) said that if this workshop could be extended it would enhance their SMK and PCK. After the presentation and reflection by T5, I facilitated balancing of chemical equations during the workshop, and I used the generic method of balancing chemical equations.

Lesson plan on balancing chemical equations

In the box below is the lesson plan prepared on chemical balancing of equations.

Topic: Balancing chemical equations

Stoichiometry describes the quantitative relationships between reactants and products in chemical reactions. Stoichiometric calculations depend upon balanced chemical equations. The coefficients of the balanced equation indicate the ratio of reactants and products taking part in the reaction.

Learning Objectives:

Learners should be able to:

- Balance chemical equation
- Identify the coefficient in the balanced chemical equations.
- Relate and compare stoichiometry in balancing chemical equations.
- Ratio of reacting substances (reactants and products)

Key words: stoichiometry, Reactants and Products,chemical equations, mole-mole problem, coefficients

Procedure:

Step 1: The teacher should outline the rules for balancing equations by inspection to Learners

a. Write a formula equation with correct symbols, formulas and subscripts
b. Count the number of atoms of each element on each side of the equation.
c. Balance atoms by using coefficients.
d. Check your work by counting atoms of each element.

Step 2: Explain what stoichiometry is.

- study of quantitative, or measurable, relationships that exist in chemical formulas and chemical reactions
- Connect importance of balanced equations with stoichiometry

3. Explain mole-mole questions: Q: How many moles of HCl are needed to react with 5.70 moles of Zn?

Step 1. Write balanced equation. $2HCl + Zn \rightarrow ZnCl_2 + H_2$

Step 2. Determine molar ratio. (2moles HCl for every 1 mole Zn)

Step 3. Cross multiply with given number of moles.

$HCl / Zn = 2 / 1 = X / 5.70$

$X = 11.40$ moles HCl

Conclusion:

- Explain the relationship between stoichiometry and balanced equations; and
- Revise the mole-mole steps.

Box 8: Lesson plan for the balancing of chemical equation

During the activity, Teacher 1 presented an equation that they failed to balance in class.

____ $AlBr_3$ + ____ K_2SO_4 $\rightarrow$ ____ KBr + ____ $Al_2(SO_4)_3$

Balanced equation: **2** $AlBr_3$ + **3** K_2SO_4 $\rightarrow$ **6** KBr + $Al_2(SO_4)_3$

After the balancing I discussed the algebraic method of balancing equations below with teachers.

An Algebraic Method of Balancing Equations

In balancing equations, we require that the same number of atoms of each element appear on both sides of the equation. The problem is more mathematical than chemical. As you might expect, these equations can be solved by general mathematical methods.

Let us consider the following equation, writing it with the undetermined coefficients a, b, x, and y as shown by:

$$a\, C_2 H_6 + b\, O_2 \longrightarrow x\, CO_2 + y\, H_2O$$

In order to determine the values of the four unknown coefficients, we must have four equations. These are supplied by the simultaneous balancing of each element. For example, we might start with the element carbon.

Carbon

One equation is obtained by equating the number of carbon atoms on the left side of the equation with those on the right. According to its formula each ethane molecule contains two carbon atoms. Therefore, there are 2a carbon atoms in ethane molecules. On the right side, each carbon dioxide molecule contains only one carbon atoms. Therefore, there are x carbon atoms on the right. Since these numbers must be equal at the end of our calculations we write

The equation

$$2a = x \text{ (Equation 1)}$$

Hydrogen

In similar manner, we can write an equation by algebraically balancing the number of hydrogen atoms:

$$6a = 2y \quad \text{(Equation 2)}$$

Oxygen

Doing the same for oxygen, we obtain

$$2b = 2x + y \text{ (Equation 3)}$$

This gives us three equations. For a simultaneous algebraic solution we need one more. Since all of the numbers representing atoms are relative, we can obtain our fourth equation by letting any one of the unknowns a, b, x, or y equal anything we wish.

.

Let us arbitrarily let a = 1 to set up our fourth equation. Then, from Equation 1, x = 2. Likewise, from Equation 2, y = 3. Placing these values for x and y into Equation 3, we get:

$$2b = 2(2) + 3 = 7$$
$$b = 3.5$$

To avoid fractions, we then multiply through by 2, getting a new set of values for the four coefficients: a = 2, b = 7, x = 4, and y = 6. If you plug in these numbers into the

Box 9: Explanatory notes about algebraic method of balancing chemical equation

Algebraic method of balancing the equation below

$NaCl + SO_2 + H_2O + O_2 \rightarrow Na_2SO_4 + HCl$

Again, we put unknown coefficients in front of each molecular species:

$xNaCl + ySO_2 + zH_2O + wO_2 \rightarrow uNa_2SO_4 + v\,HCl$

Writing down the balance conditions on each element gives:

Sodium balance:
$x = 2u$

Chlorine balance:

$x = v$

Sulphur balance:

$y = u$

Oxygen balance:

$2y + z + 2w = 4u$

Hydrogen balance:

$2z = v$

Setting u=1 arbitrarily, gives the immediate solution:

$x = 2 \quad v=2 \quad y= 1 \; z= 1$

and $2 + 1+2w = 4$, $2w = 4- 3$, $2w = 1$. $W = 1/2$.

In order to clear the fraction, we multiply all the coefficients by 2 and write down the balanced equation:

$2NaCl + SO_2+ H_2O + 1/2O_2 \rightarrow Na_2SO_4 + HCl$

Final Equation

Box 10: Using algebraic method to balance equation

The algebraic method of balancing equations is the newest chemical equation balancing method and when fully understood, balancing of equations would be very easy.

Findings from the intervention

The findings of this study further indicated that the community of practice (CoP) members acquired the professional transformations which were important breakthroughs in their careers. Transformation is defined in the Vygotskian framework as those forms of behaviour that are used between people in concrete social interactions (i.e. intermental plane to the forms of individual mental processes i.e. the intramental plane (Eun, 2008). The internalisation process does not occur automatically from a direct transformation of the intermental plane to the intramental plane, but through the use of mediators. The intervention workshops in my study were framed with activities serving as material mediators (artefacts) that aimed to solve stoichiometric problems. So, the collaborative working together of CoP members might lead to their continuing professional development. The CoP members in my study also were the human mediators enhancing transformation that resulted in higher forms of mental functions leading to their continuing professional development (CPD).

The findings of this study revealed the zone of proximal development (ZPD) of participating teachers, coming from different backgrounds and having the ability to do certain skills before the intervention. ZPD is not only for learners, but it can be applied to teachers as well. In this study the zone of proximal development enabled teachers to define their immediate needs and the shifting developmental status, which necessitated the need for the workshop intervention.

The findings also revealed the total involvement of teachers during the workshop. Teachers were actively involved in the study, volunteering willingly to partake in any task without coercion. T3 volunteered to facilitate stoichiometry mapping during the workshop intervention.

IV. RECOMMENDATIONS

The study focused on the influence of the intervention workshops with the view to improving the six Physical Science teachers' practice within a community of practice (CoP) in the Zambezi Region. The results illuminated the fact that the role and importance of the workshops and continuing professional development (CPD) cannot be overstated within a CoP.

Arising from this study, I thus offer the following recommendations for consideration by lecturers, teachers (curriculum implementers), school principals, inspectors, continuing professional development initiators and educational policy developers.

- 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;
- 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;
- This study afforded learning opportunities for Physical Science teachers and such experiences resulted in positive learning experiences for their learners in the long run as well. I therefore recommend that Physical Science teachers should promote CPD-updating bottom-up, for school management to enhance their professional development.
- From my own perspective, it is my contention that while engaging teachers in a continuing professional development (CPD), using participatory action research (PAR) within a CoP, should be done with care. I therefore recommend that university lecturers, senior education officers such as inspectors or subject advisers, who are knowledgeable about continuing professional development (CPD), should be part of a CoP.
- I recommend that teachers develop LTSMs for any academic or non-academic classroom presentations for their continuing professional development (CPD) provided it enhances learning.

Concluding Remarks

This study presented, analysed and discussed the intervention workshops and some reflections that emerged as a result of the activities. Findings and recommendationwere discussed.

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