Understanding of Macroscopic, Microscopic and Symbolic Representations Among Form Four Students in Solving Stoichiometric Problems

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ABSTRACT

The purpose of this article is to determine the levels of understanding for solving Stoichiometry problems from the aspect of macroscopic, microscopic and symbolic representations of high, average and low achieving students after infusion of metacognitive skills. Nine form four students aged sixteen years old from a secondary school in Kuala Lumpur, Malaysia were involved in this research. Data were collected through thinking aloud sessions and documents of students' worksheets. Findings showed that the level of understanding from the aspect of the macroscopic, microscopic and symbolic representations among high achieving students appeared high and solved all the Stoichiometry problems related to balancing chemical equations at the end of the infusion. The average and low achieving students also seemed to understand the three levels of representations and could solve most of the problems except that they could not understand the mole ratio in balancing chemical equations. This implies that the understanding of the mole ratio is necessary for solving stoichiometric problems.

Keywords: *Metacognition, metacognitive skills, macroscopic representation, microscopic representation, symbol representation, think aloud, Stoichiometry.*

INTRODUCTION

Chemical knowledge and understanding of our world is generated, expressed, taught, and communicated at three different "levels", traditionally called the macroscopic, the submicroscopic, and the symbolic levels. It has been one of the most powerful and productive ideas in chemical education for the past 25 years (Gilbert & Treagust, 2009a; Johnstone, 1982; Talanquer, 2011).

Stoichiometry is one of the most basic topics in learning chemistry. Hence, understanding the concept of Stoichiometry is critical to solving chemistry problems. For example, a chemistry equation is the basic concept for solving various chemistry problems. Thus, without understanding the chemistry reaction indicated in an equation, it will be difficult to solve problems (Chandrasegaran et. al, 2007; Davidowitz, et. al, 2010; Laugier & Dumon, 2004). Understanding concepts in chemistry can be achieved if the students are able to perform higher levels of mind processing using an internal representation or a mental model which has been constructed using all three macroscopic, microscopic and symbolic representations (Sunyono, Yuanita, & Ibrahim, 2015, Chandrasegaran et al., 2007; Johnstone, 1991).

According to Talanquer (2011) the nature of the macroscopic level has also been the subject of various interpretations. Some authors characterise the macroscopic level as mainly including the actual phenomena that we experience in our daily lives or in the laboratory; it is the level of the observable and tangible (Treagust, Chittleborough & Mamiala, 2003). However, others describe the macro level as representational in nature, mainly shaped by those concepts and ideas used to describe the bulk properties of matter, such as pH, temperature, pressure, density, and concentration (Chandrasegaran, Treagust & Mocerino, 2007; Gilbert & Treagust, 2009b; Nakhleh & Krajcik, 1994). Submicroscopic models of matter relate to the importance of identifying and differentiating between relevant size or length scales for the chemical theories and models of matter (Johnstone,1991). According Talanquer (2011) the visual language of chemistry can be thought of as comprised of symbols and icons used to represent the properties and behaviour of chemical substances and processes. Symbols include those signs used by convention to represent, for example, the composition of matter (e.g. H, O, H_2O), or its properties and behaviour (e.g. +, (g), →). In many cases, the signs used in chemistry combine both symbolic and iconic values (Hoffmann & Laszlo, 1991). Talanquer (2011) explained the students have an easier time grasping ideas at the macro than at the submicro levels (Johnstone, 1982, 1993).

In learning Stoichiometry, students should not only be able to learn using algorithms, but also understand the phenomena at a molecular level through imagination from the macroscopic, microscopic and symbolic aspects. Chemical learning which only focuses on algorithms will result in a shallow understanding (Dahsah & Coll, 2008). As such, the roles of imagination in chemistry learning become very important.

According to Brown et al (2003), Stoichiometry is a study of quantitative relationships in chemical formulae. Lack of skills in constructing chemical formulae, writing balanced chemical equations, lack of understanding of the mole concept, molar mass, molar volume, quantitative limiting reagents can cause students to be unable to solve Stoichiometry problems, (Glazer & Devetak, 2002; Furio, Azcona, & Guisasola, 2002). Therefore, Stoichiometry is a collective term for the quantitative relationships between the masses, number of moles and the number of particles (atoms, molecules and ions) of the reactants and products in a balanced reaction. A Stoichiometry quantity is the amount of product or reactant in a balanced reaction (Averill & Eldredge, 2007)

A chemical equation is an expression that gives the identities and quantities of the substances of reactants and products in a chemical reaction. A chemical equation displays the exact mole ratio of reactants and products which is the coefficient. Converting amounts of substances to moles, and vice versa, is the key to all Stoichiometry problems. The amounts of substances are given in either units of mass (grams or kilograms), weight (pound or tons) or volume of gases (liters or gallons) (Averil & Edredge, 2007).

Metacognition is defined as awareness and management of one's thinking or "thinking about thinking", (Kuhn & Dean, 2004). Metacognition is also thought of as the capacity to reflect upon one's actions and thoughts, (Schraw, 2001) or knowledge and regulation of one's own cognitive system (Brown, 1987). Theoretical models support two main components of metacognition: metacognitive knowledge or knowledge of cognition, and metacognitive skillfulness or regulation of cognition, (Schraw, 2001). Knowledge of cognition refers to the explicit awareness of the individuals about their cognition; that is, knowing about things (declarative knowledge), knowing how to do things (procedural knowledge), and knowing why and when to do things (conditional knowledge). Metacognitive skillfulness or regulatory metacognition is the executive component that comprises the repertoire of activities used by individuals to control their cognition while performing a task (Schraw, 2001; Schraw, Crippen & Hartley, 2006). The regulatory aspect of metacognition, as regulatory activities are believed to be integral to the development of problem-solving skills.

Several different metacognitive regulatory activities have been identified that can be grouped into three categories: planning, monitoring, and evaluating. These regulatory skills guide the problem-solving process and their refinement is believed to bring improved efficiency and learning (Sandi-Urena, Cooper & Stevens, 2012). In general, past research suggests that metacognitive strategy instruction can promote increased problem solving in the classroom (Lin, Schwartz & Hatano, 2005).

Metacognition has been shown to lead to deeper, more durable, and more transferable learning (Bransford, Brown, & Cocking, 2000). Students come to understand the difference between superficial memorization and real learning through specific classroom interventions, which were also designed to help students develop metacognitive learning strategies (Zhao, Wardeska, McGuire & Cook, 2014).

Metacognition is necessary in solving stoichiometric chemistry problems involving the visualization of the macroscopic, microscopic and symbolic levels. Solving Stoichiometry problems as a very difficult concept in chemistry subject (Sanger, 2005; Haidar & Naqabi, 2008; Chandrasegaran, Treagust & Waldrip, 2009). In Malaysia, the researches has been done by several researchers as Karuppiah (2004), Boon (2014) and Hafsah et. al (2014). Students were facing difficulties because this concept involving varieties of skills which were writing chemical formula, chemical equations and mathematics skills. Zvia Kaberman and Yehudit Judy Dori (2008) investigated stimulating chemistry students to generate complex questions enabled with a metacognitive strategy which enabled them to be aware of their own cognitive process and to self-regulate it with respect to the learning task. In relation to this, previous qualitative research has indicted that science students also model their teachers in relation to the cognitive and metacognitive skills that are demonstrated to them (Butler & Winne, 1995). Therefore, there is a clear necessity to infuse metacognitive strategies within the teaching and learning process in a science classroom (Pintrich 2002). A quantitative study used by Nyanhi (2013) revealed that the non-emphasis of chemistry teachers in the microscopic level lead to misconceptions.

The Present Study

This section will begin with how the instructional materials and tasks for infusion were carefully thought off. This will be followed by how the data was collected during infusion. The infusion was done among students of a whole class. Nevertheless, nine students (3 high achieving, 3 average achieving and 3 low achieving students) were purposefully selected. Finally, how the analysis was done is described.

Instruction materials and problem solving task.

Instruction Materials and the Stoichiometry Problem Task were prepared. Preparation of the instruction was referred to Specification of Curriculum Form Four Chemistry, Integration Curriculum of Secondary School, Ministry of Education (2005), Chemistry references and activities of metacognitive skills, (Flavell, 1987; Gama, 2004).

The Stoichiometry Problem Task consisted of seven structured Stochiometry questions. There were two sections, the first section contained three questions to construct empirical and molecular formulae. The aim of this section was to identify the ability of students to convert macroscopic to microscopic and to symbol representations. The second section contained four Stoichiometry questions involving balanced chemical equations. The aim of this section was to identify students' ability to convert from macroscopic, to microscopic then to symbols and back to macroscopic representations while solving Stoichiometry problems. The fourth and seventh questions were not given the balanced chemical equations. This was to identify the students' ability to write the balanced chemical equations. The fifth and sixth questions included the balanced chemical equations. Both the Instructional Materials and Problem Solving Task were validated by an expert panel. The expert panel consisted of two excellent chemistry teachers and two university lecturers who are in the field of metacognition and science education. Explanations for the conversion between macroscopic, microscopic and symbolic representations in Stoichiometry Problems Task is given in Table 1. The single direction arrows mean that the conversion is one way, whereas, double sided arrows mean that the conversion can be either way.

Table 1 Conversion of Macroscopic, Microscopic and Symbols representations In Stoichiometry in the Problem Tasks

Question No.	Aim of Questions	With/ without Chemical Equations	Conversion of representation
1	Empirical Formula with two elements.	Without chemical equation was given.	Macroscopic →microscopic →symbol
2	Empirical Formula with three elements.	Without chemical equation was given.	Macroscopic →microscopic →symbol
3	Empirical Formula and molecular formula with two elements	Without chemical equation was given.	Macroscopic →microscopic →symbol
4	To calculate number of particles of atoms	Without chemical equation was given.	Macroscopic → microscopic↔ symbol → microscopic.
5	To calculate the mass of product	With chemical equation was given.	Macroscopic →microscopic ↔ symbol → macroscopic.
6	To calculate the mass of reactants.	With chemical equation was given.	Macroscopic →microscopic ↔symbol → macroscopic.
7	To calculate the volume gas of product	Without chemical equation was given.	Macroscopic →microscopic ↔symbol → macroscopic.

(Modified from Chandrasegaran, Treagust & Mocerino, 2007)

Infusion of Metacognitive Skills.

Once the activities were ready, the activities for infusion of Metacognitive skills was carried out in two phases. The First phase was infusion of metacognitive knowledge and metacognitive regulation in teaching and learning. The Second stage was infusion of metacognitive knowledge and metacognitive regulation explicitly in Stoichiometry problems.

The first phase involved the teaching and learning of the topic chemical formula, chemical equation and Stoichiometry problems together with the infusion of metacognitive skills for eight weeks. These teaching and learning phase consisted of 14 sessions and each session was about 70 minutes. The Teaching and learning of metacognitive knowledge and metacognitive regulation in the first phase consisted of four stages for every lesson as shown in Figure 1.

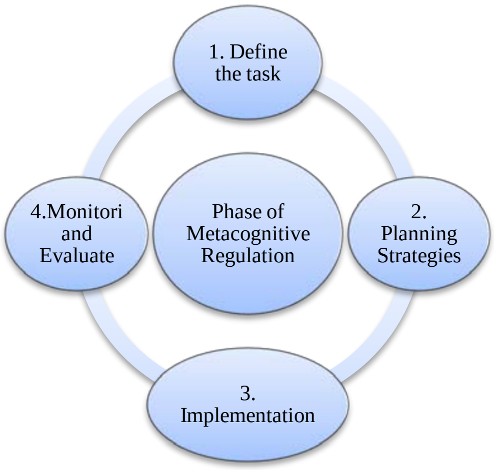

Figure 1 **: Phase of Infusion of Metacognitive Knowledge and Metacognitive Regulation**

The first stage needed students to define problem, analysis the problem and the information given. The second stage was to state the goal and design the solution plan. Third, was the implementation of the solution plan. The fourth stage was monitoring and evaluation as verification of the solution. Then there is a check as to whether all pertinent data had been used and whether the solution could have been obtained differently.

The Second phase was the infusion of metacognitive knowledge and metacognitive regulation explicitly in solving the Stoichiometry Problem Task which had seven questions. Students completed the exercises on the Stoichiometry questions using metacognition skills. The Students also needed to monitor and evaluate the Stoichiometry questions at the end of their work.

Data Collection and Analysis

There were nine participants in the study. Qualitative data collection techniques were used in the study namely from the think aloud method and supporting data were gained from documents of students' class work. Nine verbatim transcriptions of think aloud sessions were collected from the nine participants after they completed the Stoichimetry Problem Task questions.

Data transcripts of think aloud sessions were coded and categorised. Furthermore, every question in the Stoichiometry Problem Task was guided by the M-Demand for number of minimum steps needed to solve the problems. Students' answers were compared with a rubric for the questions of the Stoichiometry Problem Task. Table 2 shows the coding of each step to solve the questions and the conversion levels of representation. The steps and the conversion levels were modified with reference to the definition of macroscopic, microscopic and symbolic by Chandransegaran, Treagust and Mocerino (2007). The modifications were verified by the panel of experts.

Table 2 Solving Steps of Empirical Formula, Molecular Formula and Stochiometry Problems in Stoichiometry Problem Task

Encoding Steps	Explanation	Conversion of representation
Step Zero	Identify type of elements and mass of elements	Macroscopic
Step 1	Writing balanced chemical equation	Symbolic
Step 2	Calculating molar mass	Symbolic ↔macroscopic
Step 3	Calculating number of mole atom of element from its masses	Macroscopic ↔microscopic
Step 4(a)	Calculating mole ratio to become integer number	Microscopic↔ microscopic
Step 4(b)	Calculating the simplest mole ratio.	Microscopic↔ microscopic
Step 5	Writing empirical formula	Microscopic ↔symbolic
Step 6(a)	Determining mole ratio from balanced chemical equation	Symbolic ↔ microscopic
Step 6(b)	Calculating number of mole from balanced chemical equation	Microscopic↔ microscopic
Step 6(c)	Calculating number of atom from number of mole	Microscopic↔ microscopic
Step 7	Converting number of mole to volume of gas	Microscopic↔ macroscopic
Step 7	Converting number of mole to mass	Microscopic ↔macroscopic

(*Rearranged from Chandransegaran, Treagust & Mocerino, 2007)*

There was M-Demand for every question in the Stoichiometry Problem Task. Table 3 shows the M-demand (Niaz, 1989) for every question.

Table 3: Question and the M-Demand

Question Number	M-Demand
1	3
2	4
3	5
4	5
5	5
6	6
7	6

A rubric for every question was prepared. Table 4 shows an example of the rubric analysis for question seven.

Question 7; In industrial countries, mostly older people suffer from gastric pain. Medicine that can reduce gastric pain is called anti-acid. Anti-acid is a chemical compound which neutralises acids in the stomach. Acids in the stomach contain hydrochloric acid (HCl) which dissolve in water, which react which anti-acids to form water (H_2O), carbon dioxide (CO_2) and calcium chloride ($CaCl_2$). Generally, an anti-acid is a carbonate salt, mostly calcium carbonate, $CaCO_3$. If we see the content at the label outside the bottle, the formula of the compound is calcium carbonate ($CaCO_3$) which is an as anti-acid.

What is the volume of carbon dioxide produced if 20g of calcium carbonate is used? [Relative Atomic Mass; Ca, 40; C,12; O,16; H,1; Cl; 35.5, molar volume; 22.4 dm^3 mol^{-1} at s.t.p]

Table 4 Rubric for question Seven of the Stoichiometry Problem Task

Question 7

0. Mass of calcium carbonate is 20g. ← Step zero
1. Writing balanced chemical equation, $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$ ← Step 1
2. Molar calcium carbonate, $CaCO_3 = CaCO_3 = 40 + 12 + 16 \times 3 = 100 gmol^{-1}$ ← Step 2
3. Number of moles of 20 g calcium carbonate = 20 /100= 0.2 mol ← Step 3

6(a). Mole ratio $CaCO_3 : CO_2 = 1:1$ ← Step 6(a)

6(b). Number mol of carbon dioxide = 0.2 mol ← Step 6(b)

7. Volume of carbon dioxide = number mole x molar volume
= 0.2 x 22.4 dm^3 mol^{-1} =4.48 dm^3 ← Step 7

M-Demand= 6 (This is because Step zero does not involve conversion)

An example of analysis for a thinking aloud transcript for Syih-H (high achieving student) for question number seven of the Stoichiometry Problem Task by using the rubric for question number seven. Syih-H showed six steps as shown below,

Row number	Thinking aloud Transcript Syih-H for question seven	Step
81	Equation, $CaCO_3 + 2HCl \rightarrow H_2O + CaCl_2 + CO_2$	Step 1
82	Mole ratio $CaCO_3$: HCl : H_2O : $CaCl_2$: CO_2= 1:2:1:1:1:1	Step 6(a)
83	Molar mass $CaCO_3$ = (Ca=40) +(C=12) +(O=48)=100	Step 2
84	Mole $CaCO_3$ = 20÷(100) = 0.2 mol	Step 3
85	(Mole $CaCO_3$ = mole CO_2)	Step 6(b)
86	Mole CO_2 = 0.2 mol	Step 6(b)
87	Volume CO_2 = 0.2 x 22.4 dm^3	Step 7
88	= 4.48 dm^3	Step 7

(Excerpt from Thinking Aloud Transcript of Syih-H for Question seven)

A description table was prepared to identify students' level of understanding in term of macroscopic, microscopic and symbols in solving questions in the Stoichiometry Problem Task. The description table for analyzing students' level of understanding in terms of macroscopic, microscopic and symbolic conversion representation was prepared based on steps of problem solving by students answered correctly the questions. The descriptions were validated by the expert panel. Table 5 shows the level of understanding and explanation for steps of macroscopic, microscopic and symbolic conversion representation.

Table 5 Level of Understanding and Macroscopic, Microscopic and symbolic Conversion Representations

Level of Understanding	Explanation of Understanding in term of Macroscopic to Microscopic and to Symbol Conversion Representation
Level One	Refer to students' ability to convert all macroscopic, microscopic and symbolic representations for six to seven questions in the Stoichiometry Task and can write clearly empirical formulae, molecular formulae and balanced chemical equations, and mole ratio of reactant and product in their answer.
Level Two	Refer to students' ability to convert macroscopic, microscopic and symbolic representations for at least four of the seven questions in the Stoichiometry Problem Task and are less able to write empirical formulae, molecular formulae, balanced chemical equations and mole ratio of reactant and product in their answer.
Level Three	Refer to students' ability to convert macroscopic, microscopic and symbolic representations for only three or less of the seven questions in the Stoichiometry Problem Task and lack the ability to write empirical formulae, molecular formulae, balanced chemical equations and mole ratio of reactant and product in their answer.

FINDINGS AND DISCUSSION

Findings from data collected related to the number of terms of multiple representation used by students from transcripts of think aloud sessions were compared between high, average and low achieving students. Table 6 below shows the comparison of terms utilised by high, average and low achieving students.

Table 6: Terms of multiple representations used by high, average and low achieving students.

Terms in multiple representation	Number of terms used by high achieving students	Number of terms used by average achieving students	Number of terms used by low achieving students
Mass (*macroscopic*)	30	24	25
Volume of gas (*macroscopic*)	6	6	4
Number of mole (*microscopic*)	33	31	29
Mole ratio(m*icroscopic)*	9	8	7
Number of particles (m*icroscopic*)	6	4	3
Stoichiometry ratio (*microscopic)*	18	6	6
Writing balanced chemical Equation (*symbol)*	12	10	7
Molecular Formula(*symbol*)	9	8	7
Molar Mass(*symbol)*	18	10	13
Total	141	107	101

Findings from the analysis of a think aloud transcript for one high, average and low achieving students is shown in Table 7. The Table shows the sequence of steps for each of the seven questions in the Stoichiometry Problem Task for one selected high, average and low achieving students. By using the descriptions in Table 5, the level of understanding of students from the aspect of, microscopic and symbolic representations were determined. Table 7 shows that the high achieving student was at level 1, the average achieving student was at level 2 and the low achieving student was at level 3.

Table 7: Example of Sequence of Steps in solving questions from the Stoichiometry Problems Task For selected High, Average and Low Achieving Students

Question number and answers	M- Demand	Syih-H (one of High Achieving Students)	Nabila-A (one of Average Achieving Students)	Najiha-L (one of Low Achieving Students)
1	3	Step 3 Step 4(a) Step 5 ↓	Step 3 Step 4(a) Step 5 ↓	Step 3 Step 4(a) Step 5
Answer		SCl_3	SCl_3	SCl_3
2	4	Step 3 Step 4(a) Step 4(b) Step 5 ↓	Step 3 Step 4(a) ↓	Step 3 Step 4(a) ↓
Answer		$Na_2S_2O_3$	Na_2SO_2 (Wrong)	NaSO (Wrong)
3	5	Step 3 Step 4 Step 5 Step 5(a) Step 5(b) ↓	Step 3 Step 4 Step 5 Step 5(a) Step 5(b) ↓	Step 3 Step 4 Step 5 Step 5(a) Step 5(b) ↓

Answer		C_6H_6	C_6H_6	C_6H_6
4	5	Step 1 Step 3 Step 6(a) Step 6(b) Step 6(c)	Step 1 Step 3 (Total 2 Step)	Step 1 Step 3 Step 6(a) Step 6(b) Step 6(c)
Answer		4.515×10^{23} atom of copper	Wrong answer	4.515×10^{22} (Wrong answer)
5	5	Step 1 Step 3 Step 6(a) Step 6(b) Step 7	Step 1 Step 3 (2 Step)	Step 3 Step 7 (2 Step)
Answer		Mass=0.36 g	Wrong answer	0.36
6	6	Step 1 Step 2 Step 3 Step 6(a) Step 6(b) Step 7(a) Step 7(b)	Step 1 Step 2 Step 3 Step 6(a) Step 7(a) Step 7(b)	Step 1 Step 2 Step 3 Step 7(a) (4 Step)
Answer		Mass of HCl = 2.7 kg Mass of NH_3= 1.3kg	Mass of NH_3 =1.275kg Mass of HCl=2.73kg	Mass of NH_3=1271.09
7	6	Step 1 Step 2 Step 3 Step 6 (a) Step 6(b) Step 7	Step 1 Step 2 Step 3 Step 6(b) Step 7 (5 Step)	Step 1 Step 2 Step 3 Step 6(a) Step 6(b) Step 7
Answer		Volume of carbon dioxide, CO_2 =4.48 dm^3	4.48 dm^3	4.48dm^3
Level of Understanding		First Level	Second Level	Second Level

To elaborate further the results in Table 7, an example from the high achieving student Syih will be discussed. Syih could understand the conversion of the macroscopic concept to the microscopic level and then to the symbolic representation and vice versa for all the seven questions in the Stoichiometry Problem Task. Syih was also able to solve all the empirical formulae, molecular formulae in all the Stoichiometry questions. Syih could write balanced chemical formulae, and showed understanding of the mole ratio concept (symbolic level of representation). She was also able to apply the mole ratio or the Stoichiometry ratio from the balanced chemical equation to elicit the number of moles and then to mass or volume gas of products. Figure 2 illustrates the answer for question 7 of the Stoichiometry Problem Task by Syih. Nevertheless, Syih did not clearly indicate the units to be used.

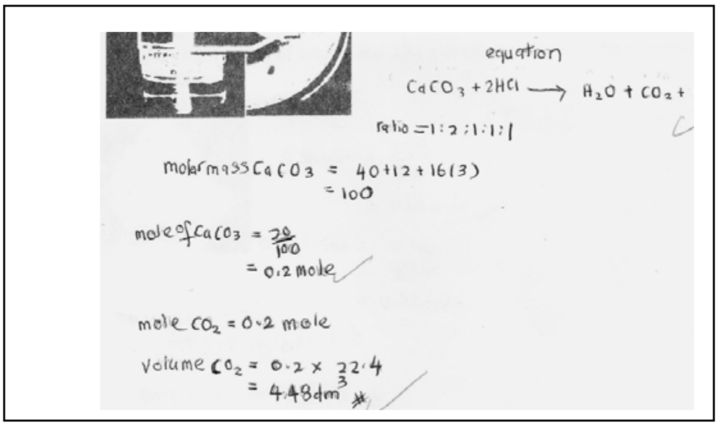

***Figure 2*: Example answer of Syih- for question seven – level 1**

With reference to Figure 2, it can be seen that Syih showed the correct balanced chemical equation in step 1. Step 2 shows the calculation for molar mass of calcium carbonate, $CaCO_3$ is equal to one hundred. Step 3 shows the calculation for the mole number of calcium carbonate which was equal to 0.2. Step 6(a) shows the Stoichiomery ratio from the balanced chemical equation which was 1:2:1;1:1. Step 6(b) shows the mole of carbon dioxide, CO2 which was equal to 0.2. Step 7 shows the calculation and the answer of the volume of carbon dioxide, CO2 which was equal to 4.48 dm^3. Therefore, Syih demonstrated all the conversions of macroscopic, microscopic and symbolic representations for question number seven. In the same way, the analysis was done for the selected average and low achieving students.

Figure 3 shows an example of Nabila's work (an average student) for question seven. The chemical equation written by Nabila-was not balanced but the mole ratio is correct, so the answer was correct. Hence, it appears that although Nabila could not convert from the symbolic level to the microscopic level and then to the macroscopic level, because the mole ration was correct, the problem was solved.

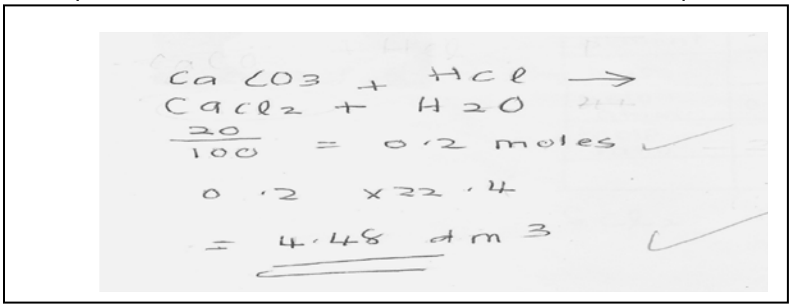

***Figure 3*: Example of Nabila's answer for question seven – level 2**

Figure 4 shows Najiha's (low achieving student) answer to question seven in the Stoichiometry Problem Task. She has written an incorrect chemical formula of calcium chloride but the correct chemical equation, as she probably managed to convert through all the three levels.

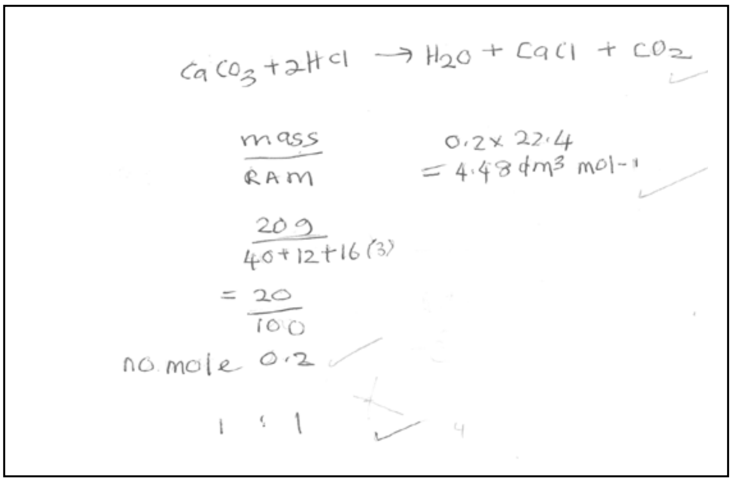

***Figure 4*: Example answer of Najiha for question seven – level 3**

Difficulties encountered by the average achieving and low achieving students were writing balanced chemical equations and to identify the mole ratio or Stoichiometry ratio in balanced chemical equations. Nevertheless, data analysis has indicated that infusion of metacognitive skills supported Stoichiometry Problem solving, in enhancing the ability to convert through the three levels as a form of scaffolding towards the teaching and learning process of Stoichiometry to push students to achieve a higher level of achievement along the Zone of Proximal development as proposed by Vygotsky.

Past studies such as by Hafsah et al. (2014) have also concluded that students' success in Stoichiometry problem solving depends mainly on their understanding of the concept of mole and conceptual understanding of the problems. Students have difficulties in 'making sense' of the chemical reaction itself. Students difficulties in having the conceptual understanding of the problem, namely, being able to translate the worded problems into a suitable chemical and mathematical equation, and using the correct formula to calculate the mole, before they able to solve the problem. In addition, Fach, Boer and Parchman, (2007) also found that students lack understanding in the number of moles and number of particles also contributed to being not able to solve Stoichiometry problems.

CONCLUSION

Based on the results in the study, it appears that students of different achievement can slowly succeed in solving Stoichiometry problems by teaching metacognitive strategies, especially in being able to convert their visualization from macroscopic to microscopic and to symbolic levels. However, the medium and lower achieving students perhaps need more time to enhance their understanding and application of the mole concept which can be seen in their errors in balancing equations.

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