# Application of Multiple Representation Levels in Redox Reactions among Tenth Grade Chemistry Teachers

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## ABSTRACT

Utmost important is students should be able to understand chemistry concepts at multiple representation levels and integrate between these levels. However, previous research showed that students face difficulty in this aspect. Thus, this study embarked into investigating how chemistry teachers apply these multiple representation levels in teaching redox reactions through verbal interaction. Ten chemistry secondary school teachers in Kuala Lumpur, Malaysia were involved in this study. Data were collected using observation and semi-structured interview. Analysis of data was done quantitatively to determine the percentages of verbal interaction at multiple representation levels. Data were also analyzed qualitatively to determine the pattern of application of multiple representation levels. Findings showed that teachers emphasized more on macroscopic level compared to submicroscopic and symbolic levels. It was found that students' statement on multiple representation levels dominates interaction that occurred during chemistry lessons observed. Furthermore, there were three types of patterns of integration between multiple representation levels illustrated by chemistry teachers. Eighty percent of the respondents showed incomplete integration between these multiple representation levels. In conclusion, chemistry teachers should be aware and understand the application of these multiple representation levels in order to produce chemically literate students.

**Keywords:** Multiple Representation Levels; Macroscopic; Submicroscopic; Symbolic; Verbal Interaction.

## INTRODUCTION

In Malaysia, students start learning chemistry as a subject in tenth grade. The students will learn many concepts in chemistry in two years before they are required to sit for the public examination prepared by Malaysian Education Certificate at the end of Form Five (Year 11). In Curriculum Specifications Chemistry for Secondary Schools developed by Curriculum Development Centre, there are nine chapters in Tenth Grade (Year 10) and five chapters in Form Five (Year 11) (Curriculum Development Centre, 2005; Bahagian Pembangunan Kurikulum [Curriculum Development Centre, 2012). Allocation of time for chemistry lessons specified by the Ministry of Education (1990) is 160 minutes per week. With so many concepts to be learned and being a novice learner in scientific community, this

subject is considered as difficult. This is supported by Johnstone (2000); Sirhan (2007); Tsaparlis, Koliulis and Pappa (2010) and Noor Dayana et al. (2010) which stated that chemistry is considered as one of the tough subject.

Chemistry involves understanding and application of chemical concepts. Chemistry concept or knowledge can be represented at multiple representation levels which are also known as chemistry triplet (Talanquer, 2011) or triplet relationship (Gilbert and Treagust, 2009). These multiple representation levels are the observable world (macroscopic), model (submicroscopic world) and symbolic level (Johnstone, 1991, 2000; Treagust, Chittleborough and Mamiala, 2003; Jaber and BouJaoude, 2012). Johnstone (1993) stated that chemistry which was often discussed in terms of macro and symbolic level, which excludes the submicro part. Therefore, this study attempts to study the verbal interaction at multiple representation levels in redox reactions lessons. These forms of the subject are the macro and tangible: what can be seen, touched and smelt; the submicro: atoms, molecules, ion, structures; and symbolic: the representational symbols, formulae, equations, molarity, mathematical manipulation and graphs (Johnstone, 2000). He added that in order to 'fully understand' chemistry, more emphasis should be given to submicro and symbolic levels (Johnstone, 2000). Jaber and BouJaoude (2012) pointed that failure to understand chemistry at multiple representation levels could lead to alternative conception and prevent students to learn and appreciate chemistry. Not only understanding at these levels are important, students should also link between one level to the other or integrate these levels as these chemical representations complement each other (Johnstone, 2000; Treagust, Chittleborough and Mamiala, 2003) (see Figure 1).
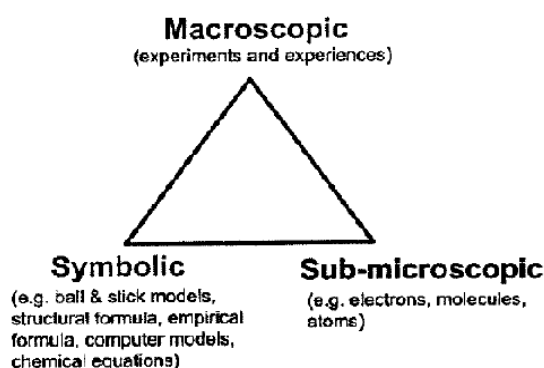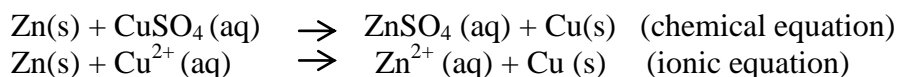


**Figure 1:** *Three Levels of Representation in Chemistry (Johnstone, 1991; Treagust, Chittleborough and Mamiala, 2003)*

In other words, to understand chemistry, it needs a deep and thorough understanding of a concept. This is the key component in learning chemistry. There is evidence which showed that chemistry students often face difficulty with regards to this chemistry triplet (Gilbert and Treagust, 2009). Students unable to relate observations made (macroscopic) to submicroscopic and symbolic world. Understanding at submicroscopic level involves understanding particulate nature of matter. However, due to students' inability to visualise the particles, unable to make connection between macro and submicroscopic add to the challenge for students to learn chemistry. Eventually, due to the complexity of these multiple representation levels, which is the nature of chemistry itself left the students fell bored, frustrated and ended up with memorising the facts. They 'learn' chemistry through rote learning as reported by Nurfaradilla et al. (2010). This rote learning acts as barrier to meaningful learning as stated by Dori and Hameiri (2003).

The application of these multiple representation levels in redox reactions is as follows. For example, a reaction between zinc and copper (II) sulphate solution, students could do some observation at the end of the reaction. The students could have observed that, for

example, a brown solid is deposited. That observation represents the macroscopic level. In order to understand what actually happens in the reaction, we have to look at submicroscopic and symbolic level, which is the type of particles, took part in the reaction. In the example of displacement reaction, zinc metal which is all in atom form will displace copper two ions from its salt solution (submicroscopic). The reaction can be represented by the following chemical and ionic equation (symbolic).

$$Zn(s) + CuSO_4\,(aq) \quad \rightarrow \quad ZnSO_4\,(aq) + Cu(s) \quad \text{(chemical equation)}$$
$$Zn(s) + Cu^{2+}\,(aq) \quad \rightarrow \quad Zn^{2+}\,(aq) + Cu\,(s) \quad \text{(ionic equation)}$$

Sadly, in many experiments, students were being taught to write 'standard' answer (Tan et al., 2009). If the teacher did not explain what happens in the reaction occurred and by writing chemical and ionic equation, obviously the students' understanding was merely at macroscopic level.

Redox reactions concepts were mainly interaction between macroscopic and submicroscopic world, which is the source of difficulty for many chemistry learners as reported by Garnett and Treagust (1992); De Jong, Acampo and Verdonk (1995); Sanger and Greenbowe (1997); Tsaparlis (2007), and also difficult for teacher to teach (De Jong, Acampo and Verdonk, 1995). Furthermore, there is lack empirical studies on this topic (De Jong and Treagust, 2002) in terms of student's difficulties in learning. This topic was chosen also as it is related to oxidation and reduction which students will learn in Year 11 (Curriculum Development Centre, 2005; 2012). Therefore it is of utmost important that these students grasp and master the concepts in this topic. Nevertheless, explanation of relevant concepts in textbooks were found to be insufficient to provide students with adequate conceptual knowledge of the topic (Ozkaya, 2002). This is where teacher plays an important role here. The way teacher explain the concept is more important than the quantity of concepts impart to the students. Sirhan (2007) mentioned that information delivered to students is not always learned. If teacher fails to explain chemistry concepts at multiple representation levels, it may leads to misconceptions.

Classroom learning involves interaction, between teacher and students (Suchman, 1966; Brown, 1975; Chamberlain and Llamzon, 1982), or between student and other students (Suchman, 1966). According to Shahabuddin, Rohizani and Mohd. Zohir (2003), there are two types of interaction which occur in classroom; verbal interaction and non-verbal interaction. This study focused on verbal interaction as verbal interaction is the common type of interaction that occurred in classroom claimed by Chamberlain and Llamzon (1982). Furthermore, verbal interaction could be used to investigate the process of teaching and learning in classroom as stated by Flanders, 1970; Eggleston, Galton and Jones, 1975; Malamah-Thomas, 1987; Mohamed Najib, 1997; Brandon et al., 2008). Three main components of verbal interactions are teacher's talk, student's talk and silence (Flanders, 1970; Eggleston, Galton and Jones, 1975; Malamah-Thomas, 1987) or confusion (Mohamed Najib, 1997). Teacher's talk could be either teacher's question or teacher's statement; and student's talk could represents either student's question or student's statement. Although research suggest the integration of these three aspects and the importance of these aspects (De Jong and Taber, 2007; Gilbert and Treagust, 2009; Tan et al., 2009), yet there is lack empirical research on how chemistry teachers at secondary schools apply multiple representation levels during chemistry lesson. Hence, this study addresses this issue to provide insight into application of triplet relationship in chemistry lesson.

This study was designed to describe and provide explanation on application of multiple representation levels among chemistry teachers. In specific, research questions are as follows:

1) What are the verbal interactions at multiple representation levels emphasised by chemistry teachers in teaching redox reactions?
2) How do chemistry teachers link between these multiple representation levels in teaching redox reactions?

**METHODOLOGY**

The following section discuss about setting and participants, instrument and data analysis.

### a) Settings and participants

This mixed method study involves seven urban secondary schools, in Kuala Lumpur, Malaysia. Quantitative data was first collected, analysed, followed by qualitative data. Qualitative data was used to explain findings of quantitative data as stated by Creswell (2009). Therefore, these two types of data were needed as they complement each other to enhance understanding of the application of multiple representation levels among chemistry teachers.

This study involved ten chemistry teachers with teaching experience ranging between one to twenty five years of teaching chemistry. The students were of mixed ability. General information about the background of these teachers, who were the focus in this study (see Table 1).

**Table 1:** *Participant Information*

| Participant | Gender | Academic Qualification | Specialisation | Teaching experience (year(s)) | Academic Responsibilities |
|---|---|---|---|---|---|
| R01 (SMK A) | Female | Bachelor of Education | Chemistry | 5 | Chemistry teacher |
| R02 (SMK B) | Male | Bachelor of Education | Biology/Chemistry | 2 | Chemistry teacher |
| R03 (SMK C) | Female | Bachelor of Education | Biology/Chemistry | 3 | Chemistry teacher |
| R04 (SMK D) | Male | Bachelor of Education | Mathematics/Chemistry | 7 | Chemistry teacher |
| R05 (SMK E) | Female | Bachelor of Education | Chemistry | 8 | Head of Chemistry Panel |
| R06 (SMK E) | Female | Bachelor of Education | Chemistry | 3 | Head of Chemistry Panel |
| R07 (SMK F) | Female | Bachelor of Education | Biology/Chemistry | 15 | Head of Science and Mathematics Division |
| R08 (SMK G) | Female | Bachelor of Education | Chemistry | 1 | Head of Chemistry Panel |
| R09 (SMK G) | Female | Bachelor of Education | Chemistry | 25 | Head of Science and Mathematics Division |
| R10 (SMK H) | Female | Master of Education | Chemistry | 10 | Chemistry teacher |

R: Respondent

The data was collected over six months and involved two major data collection tools, which are observation instrument and semi-structured interview. Each teacher was observed four times. Duration of each lesson lasted between 70 to 80 minutes. Observations were done based on date agreed between the researchers and the respondent. Field note was also used to

complement data obtained from the two major data collection methods. The researchers explained the purpose, instruments that will be used and the nature of the study which involved recording the observations. Researcher also emphasised that observations will be recorded and these recordings are only done to cater the purposes of this study and the participants are ensured of confidentiality and anonymity of the participants. Only the researchers have access to the recordings. As this study involved video and audio recording of lessons observed, teachers are selected based on their consent given to participate in this study.

### b) Instrument

An observation instrument, known as Observation Instrument in Inquiry Teaching through Verbal Interaction (OIITVI) was built to identify the verbal interaction of teacher and students at multiple representation levels in chemistry lessons (see Appendix 1). This instrument was built based on modification of previous existing classroom observation instruments developed by Flanders (1970), Eggleston, Galton and Jones (1975); Mohamed Najib (1997), Brandon et al. (2008) and Tay (2010).  Time sampling was every three seconds as used by other researchers (Flanders, 1970; Mohamed Najib, 1997 and Tay, 2010). Face validity and content validity has been obtained from two senior lecturers specialised in chemistry education and one Master chemistry teacher to ensure that this instrument (OIITVI) able to determine the inquiry teaching practices in chemistry lessons. In terms of reliability of this observation, inter-rater reliability was applied as suggested by Creswell (2008). Hence, the researcher and two other chemistry lecturers categorise a recorded chemistry lessons of 30 minutes using the instrument (OIITVI). Kappa value which measures the agreement between observers was used to express the agreement between observers. Calculated kappa values obtained were .977 and .808 for the first and second lecturer respectively. These values showed high agreement between observers (Viera and Garrett, 2005). Besides that, to ensure the reliability of data obtained from the OIITVI, recorded chemistry lessons were listened twice.

These teachers were then interviewed based on the result obtained from the observation. The interviews were conducted in order to explore and understand in detail about chemistry teacher's inquiry teaching practices (Bennett, 2003). Example of questions asked were "Are you aware of macroscopic, submicroscopic and symbolic terminology?", "Based on observations, you tend to focus more on macroscopic aspect compared to submicroscopic and symbolic levels. Why?" and "How do you emphasise on these multiple representation levels aspect in teaching chemistry?".

Protocol of the interviews was as suggested by Creswell (2008).
Date of interview :
Time      :
Venue      :
Interviewer    :
Respondent    :

These interviews were audio recorded after respondents' consent was obtained and transcribed verbatim.

### c) Data Analysis

Process of analysing data was done concurrently with the collection of data. Chemistry lessons observed was first categorised based on categories in the observation instrument, Observation Instrument in Inquiry Teaching through Verbal Interaction (OIITVI) (see

Appendix 1). Categories 1a until 1p represent teacher's questions and 2a until 2w represents teacher's statement. On the other hand, student's question categories and student's statement categories were represented by categories 3a, 3b, 3c; and 4a, 4b, 4c respectively. Descriptive statistics in terms of percentage of verbal interaction at multiple representation levels were then calculated. The results were reported according to four main categories of verbal interaction observed (teacher's question, teacher's statement, student's question and student's statement). Data were analysed using Statistical Package for Social Sciences PASW Version 18.0.

Analysis on how teachers integrate these multiple representation levels was done manually. All recorded chemistry lessons and interviews were transcribed verbatim. In order to ensure validity of the findings, the participants were showed the transcribed classroom observation lessons and interviews made. Overall, the participants agreed with the transcribed lessons and interviews made by the researcher.

## FINDINGS and DISCUSSION

This part discusses findings on distribution of multiple representation levels in redox reactions and how teachers apply multiple representation levels in teaching.
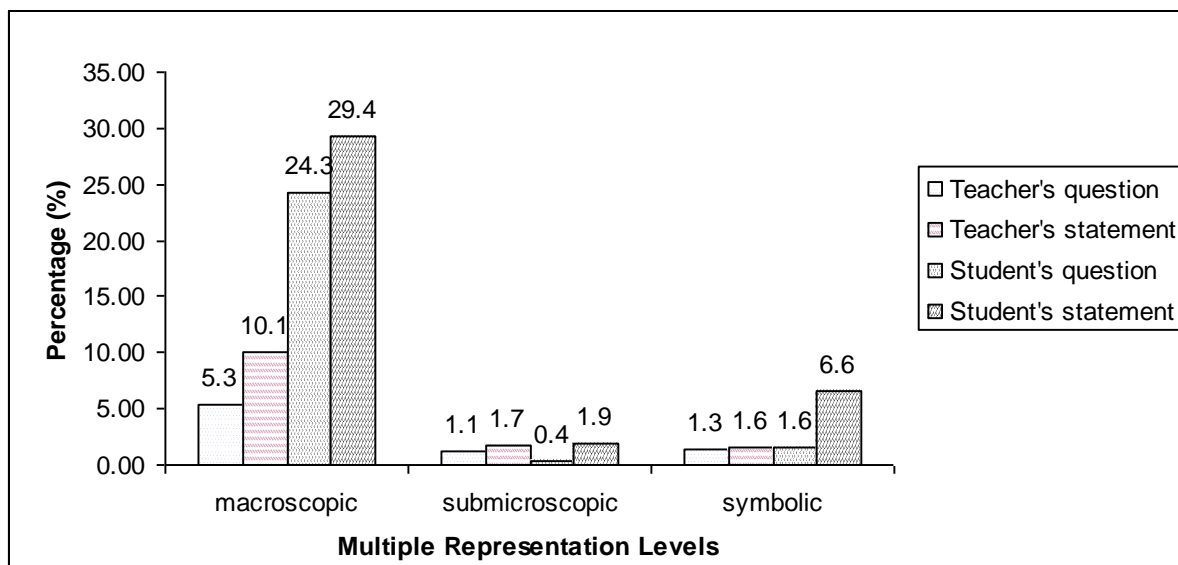
### What Are The Verbal Interactions of Multiple Representation Levels Emphasised by Chemistry Teachers in Teaching Redox Reactions?

Overall distributions of multiple representation levels are stated in terms of percentage which is shown in Figure 1. Chemistry teachers in this study tend to focus on macroscopic level, followed by symbolic level and the least were submicroscopic level. Teacher's focus on macroscopic level was also reported by Tan *et al*. (2009). This finding differed from findings from previous researchers, Garnett and Treagust (1992), Sanger and Greenbowe (1997) whom stated that electrochemistry topic, which also includes redox reactions deals mainly with macroscopic and submicroscopic levels. This showed that chemistry teachers showed a slight deviation from the common teaching practice in this topic. Submicroscopic level is very important, especially in this topic, as it explains the macroscopic aspect (observations made during the laboratory sessions) and explain a chemical concept in detail as mentioned by Johnstone (2000).
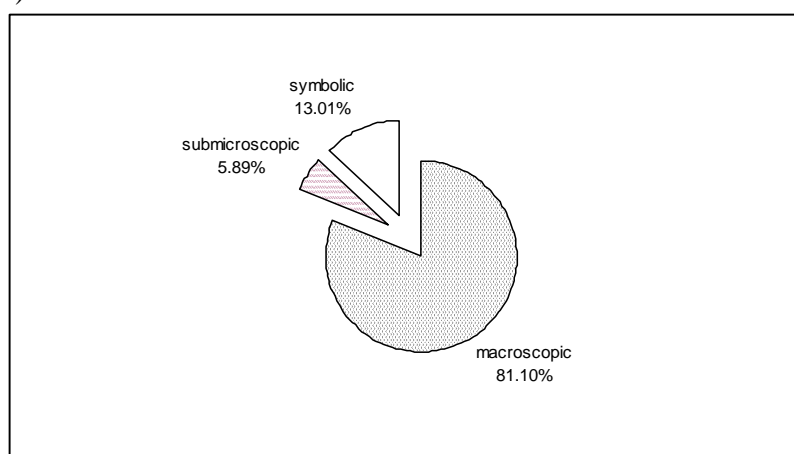


**Figure 2:** *Overall Distribution of Multiple Representation Levels in Redox Reactions*

Figure 3 shows a detail analysis of distribution of multiple representation levels in terms of teacher's question, teacher's statement, student's question and students' statement.

**Figure 3:** *Distribution of Multiple Representation Levels in Redox Reactions according to Categories of Verbal Interaction*
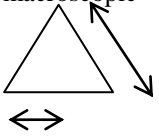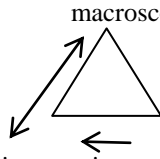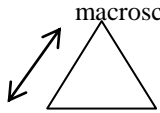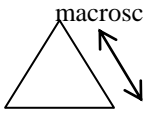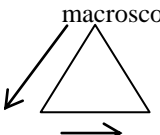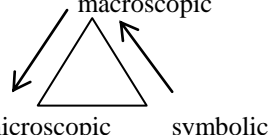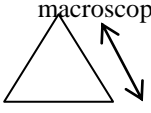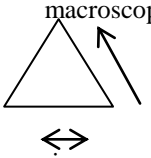
Surprisingly, finding from this study showed that the teaching and learning process is student-centred as percentage of student' talk, either questions or statements are higher than percentage of teacher talk. Student's statement dominates the interaction that occurred in the classroom which is 37.9%. Domination of students' verbal interaction was mostly due to respondents' encouragement and positive attitudes towards students' involvement during teaching and learning process. Students were seen giving response to teachers' questions or statements.

In terms of teacher's talk at multiple levels of representation (macroscopic, submicroscopic, symbolic), percentage of teacher's statement (13.4%) is higher than percentage of teacher's question, which was only 7.7%.
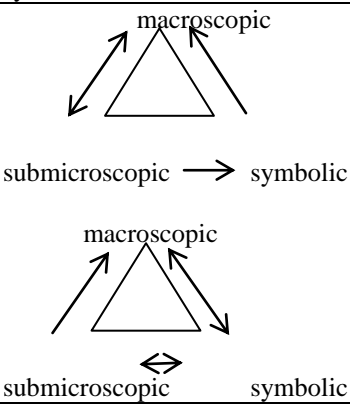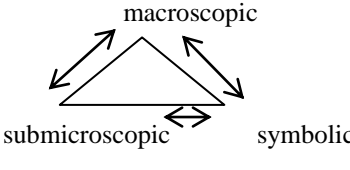
**How Do Chemistry Teachers Link Between These Multiple Representation Levels in Teaching Redox Reactions?**

Based on the transcribed classroom observations, line by line coding was made under three major themes. Three major themes are macroscopic, submicroscopic and symbolic. There are two types of arrows presented in this table. The single headed arrow, $\longrightarrow$ represents shift from one representation level to another. The double headed arrow, which is represented by $\longleftrightarrow$ means there is continuous link between the two representational levels. As shown in Table 2, there are three patterns of integration of multiple representation levels in teaching redox reactions.

Table 2: *Patterns of Application of Multiple Representation Levels*

| Type of Pattern | Respondent | Pattern | Explanation |
|---|---|---|---|
| 1 | R01, R02, R03, R04, R05, R06, R07, R08, R09, R10 | *(diagrams of macroscopic–submicroscopic–symbolic triangles with arrows)* | Incomplete integration of multiple levels of representation as it involves two levels of representation only. Furthermore, there is no continuous discussion on these three levels as represented by single headed arrow (⟶). |

| | | | |
|---|---|---|---|
| | | symbolic | |
| 2 | R05, R07 | macroscopic<br><br>submicroscopic → symbolic<br><br>macroscopic<br><br>submicroscopic ⟷ symbolic | Incomplete integration of multiple levels of representation. Although the three levels of representation were applied in discussing a concept, however, there is no continuous discussion on these three levels as represented by single headed arrow (→). |
| 3 | R06, R10 | macroscopic<br><br>submicroscopic ⟷ symbolic | Complete integration of multiple levels of representation. The three levels of representation were applied in discussing a concept, and there is continuous discussion on these three levels as represented by double headed arrow (⟷). |

Type of pattern 1 showed the emphasis and integration occurred between two representation levels only. All respondents showed this type of pattern during the observed chemistry lessons. This type of pattern showed incomplete integration of multiple levels of representation as it involves two levels of representation only. Example of an episode of chemistry lesson that illustrates pattern 1:

[Context of lesson: Electrolysis of lead (II) bromide]

Teacher:    See here... There is little bit of grey solid formed at this electrode. This electrode, is it anode or cathode? → macroscopic

Student 1:    So, at cathode, were the electrons accepted or released? → submicroscopic

Accepted.

[Respondent R01]

Nevertheless, it was found that there were two other types of patterns. Besides type of pattern 1, two respondents (R05 and R07) showed pattern 2. This type of pattern showed emphasis occurred on three levels, however the integration is incomplete.

Example of episode of lesson that showed pattern 2 as shown below:

[Context of lesson: Reaction between magnesium and copper, copper and copper metals]

Teacher    :    Which metal is more electropositive?
Ok…the position is higher in the electrochemical series?
Student 1    :    Copper. → macroscopic
Student 2    :    Magnesium.
Teacher    :    Ok. Magnesium metal.
Ok, why is magnesium more electropositive than copper?

| | | |
|---|---|---|
| Student 3 | : | Tendency to release electron higher. ⟶ submicroscopic |

| | | |
|---|---|---|
| Teacher | : | Because the position higher in? |
| Student 4 | : | Electrochemical series. ⟶ macroscopic |

| | | |
|---|---|---|
| Teacher | : | Which metal will donate the electrons? ⟶submicroscopic |
| Student 2 | : | Magnesium. |

| | | |
|---|---|---|
| Teacher | : | Ok, so, magnesium will donate the electrons. Ok, how many electrons? (Teacher writing half equation at white board) ⟶ symbolic |
| Student 1 | : | Three. |
| Student 2 | : | Two. |
| Teacher | : | Ok. Two. |

[Respondent R02]

In type 1 and type 2 patterns displayed, these respondents do not ask probing questions to enhance discussion on redox reactions. Questions asked were merely based on questions in the chemistry textbooks or modules. Consequently, there was lacking of integration between these three levels of representations.

Meanwhile, respondents R06 and R10 also displayed type of pattern 3, besides than type of pattern 1. This type of pattern 3 showed complete linkage between these three representation levels. The best practice of teaching chemistry is showed by type of pattern 3.

However, only two teachers (20%) of the participants showed this pattern.

Example of an episode of the lesson which showed this pattern is as shown below:
[Context of lesson: Displacement reaction]

| | | |
|---|---|---|
| Teacher | : | Do you observe what happened? |
| Student | : | Yes. |
| Teacher | : | Really? If yes, Danisa, what happened to the magnesium ribbon? |
| Danisa | : | Corrode… |
| Teacher | : | Other than that? ⟶ macroscopic |
| Student 1 | : | Thinner. |
| Teacher | : | Other than thinner? |
| Student 2 | : | Dissolve. |
| Teacher | : | Yes. Magnesium dissolves or becomes thinner. How about copper plate, Ailia? |
| Ailia | : | Gas bubbles are released at copper plate. |

| | | |
|---|---|---|
| Teacher | : | Is it the copper that releases the hydrogen? |
| Student 3 | : | No. |
| Teacher | : | From the…? |
| Student | : | Solution. ⟶ submicroscopic |
| Teacher | : | Ok, magnesium atom will form? Magnesium? |
| Student 3 | : | Ion. |

| Teacher | : | Yes, it will forms magnesium ion, Mg two plus. Where do we add these electrons? (Teacher writing equation on the white board) | → symbolic |
| Student | : | On the right. | |
| Teacher | : | Ok, and then put the two in front. (Teacher balancing half ionic equation). | |

| Teacher | : | Initially, magnesium is in the form of metal. Then, it dissolves. | → macroscopic |

| Teacher | : | Why it dissolves? As it becomes? Ion. Where do the electrons go? (showing the equation) | → symbolic |

| | | Electrons will flow to copper plate. What are the ions present in the electrolyte? | → submicroscopic |

| | | Na plus, H plus… (Teacher writing the chemical formula on the white board) | |
| Student 2 | : | OH minus. | → symbolic |
| Teacher | : | And? | |
| Student 2 | : | H plus. | |
| Teacher | : | The voltmeter reading shows the flow of electron. → submicroscopic | |
| | | That is the reason the voltmeter shows a reading. → macroscopic | |

[Respondent R06]

[Note: Danisa and Alia – pseudonym]

The example above showed that respondent R06 emphasises on these multiple levels of representation and at the same time showed complete integration between these levels. Based on observations made by students during practical work (macroscopic level), the teacher linked those observations made (magnesium ribbon dissolves and gas bubbles released at copper plate) to the theory to explain the phenomena (magnesium atom will forms magnesium ion - submicroscopic level). Not only that, half equations of the reaction were discussed (symbolic level). Hence, teachers should assist students in understanding chemical concepts at multiple levels of representation to enhance their conceptual understanding as suggested by Valanides, Nicolaidou and Eilks (2003); Tan *et al*. (2009); Nieves, Barreto and Medina (2012). This is because these three levels of representations complement each other (Johnstone, 2000). Furthermore, students' reasoning and problem solving skills could be improved when they learn scientific concepts at multiple representation levels as stated by Nieves, Barreto and Medina (2012).

In order to investigate why teachers lacked practice of integration between these multiple levels of representation, semi-structured interviews were carried out. The finding from the semi-structured interviews revealed that all these teachers could not define the terms "macroscopic, submicroscopic and symbolic" as they were seemed not to be aware of these terms. Example of the transcribed interview:

Researcher          :          Are you aware of macroscopic, submicroscopic and symbolic
                                    terminology?

Respondent 03:          Ah? What is that?

After the researcher explained about these three terminologies, further question was asked.

Researcher          :          You tend to focus on macroscopic compared to submicroscopic and
                                    symbolic. Could you explain why?

Respondent R03:          Based on my experience, as these students I am teaching are weak
                                    students, hence, I focused more on macroscopic level which were
                                    mostly asked in the examination.

Lacking in full integration at these multiple representation levels also may be due to teachers were not exposed to these terminologies and depends on ability of the students in the class. Treagust and Chandrasegaran (2009) emphasized that teachers should be aware of these terminologies and need to apply these multiple representation levels in explaining chemical phenomena during classroom instruction. Teachers' implications of integrating these multiple representation levels could lead to their students' understanding of chemistry concepts.

## CONCLUSION and IMPLICATION

The aims of this research were to explore the differences in attitudes towards science among the Malay and Aboriginal Year 4, 5 and 6 primary students, specifically by gender, grade level, and ethnicity. Since there was no two-way interactional effect between gender and grade level, the main effects for gender as well as grade level could therefore be interpreted in a straightforward manner without any concern of moderating effect. The findings indicated that, while there was no significant difference in attitudes towards science between the boys and the girls, there was a statistical significant difference by grade level in which Year 5 students had more positive attitudes towards science than Year 4 students, and that Year 6 students had more positive attitudes towards science than Year 4 students. However, there was no significant difference in attitudes towards science between Year 5 and Year 6 students. In terms of ethnicity, the Malay students have more favourable attitudes towards science as compared to the Aboriginal students.

This study shed some light in bridging the gap between theory and practice of multiple representation levels in chemistry lessons. Although many researchers suggest the usage of integration on multiple representation levels, how chemistry teachers make link between these three representation levels is still unknown. Finding of this study showed that majority of the chemistry teachers emphasised on macroscopic aspect, followed by symbolic and the least was submicroscopic aspect. Perhaps teachers could use model as suggested by De Jong and Taber (2007) or video animation to illustrate particles involved during a chemical reaction in redox reactions. Besides that, hands-on activity that incorporates these three levels of representation as suggested by Nieves, Barreto and Medina (2012); González-Sánchez, Ortiz-Nieves and Medina (2014) are needed to enhance the application of these three levels during classroom instruction.

Percentage of student's talk is higher than teacher's talk, which showed a positive sign towards student-centred classroom. In terms of the manner teacher integrates these multiple representation levels in classroom, there is lacking of the integration between these three

levels, as it involves only two levels of representation (pattern 1) (see Table II). Teachers should try to link observations made at the macroscopic level to explain the observations made at submicroscopic level as mentioned by Tsaparlis (2009). Based on the finding from the interviews, chemistry teachers should be aware of these terminologies of multiple representation levels. Although, most of these teachers specialised in chemistry education, they have not heard of these terms and therefore could not define when asked by the researchers.

Application of these three levels of representation is the key model for chemical education (Gilbert and Treagust, 2009). Therefore, lecturers of higher institution should look into this matter seriously in preparing well-versed pre-service teachers in these aspects. Furthermore, in-house training should be organised for in-service teachers to expose these teachers with these multiple representation levels and the application of it in chemistry lesson. This is necessary as teachers are the key person in producing chemically literate students.

As this study focused on redox reaction, in future, an extensive in-depth study on other chemistry topics which involves verbal and non-verbal aspects of interactions is necessary to provide a broader view of application of multiple representation levels.

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**APPENDIX 1:** *Observation Instrument in Inquiry Teaching through Verbal Interaction (OIITVI)*

| Category | | | Reference | Representation level |
|---|---|---|---|---|
| Teachers' question (Flanders, 1970; Mohamed Najib, 1997; Egglestone, Galton and Jones, 1975; Brandon *et al.*, 2008; Tay, 2010) | Content | 1a. to relate students' prior knowledge and lesson | Eggleston, Galton and Jones,1975;  Tay, 2010 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 1b. to arouse students' thinking of a concept | Tay, 2010 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 1c. to obtain meaning of a definition/principle/concept | Mohamed Najib, 1997; Brandon *et al.*, 2008 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | Science process skills | 1d. Observing | Eggleston, Galton and Jones,1975 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 1e.  Classifying | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 1f.   Measuring and Using Numbers | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 1g.   Making Inferences | Egglestone, Galton and Jones, 1975, Mohamed Najib, 1997 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 1h. Predicting | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 1i. Communicating | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 1j.  Using Space-Time Relationship | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 1k. Interpreting data | Egglestone, Galton and Jones, 1975 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 1l. Defining operationally | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 1m. Controlling variables | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 1n.  Making hypothesis | Egglestone, Galton and Jones, 1975; Mohamed Najib, 1997 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 1o.  Experimenting | Egglestone, Galton and Jones, 1975; Mohamed Najib, 1997 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | Not related to content/science process skills | 1p. Class management | Tay, 2010 | |
| Teachers' statement (Egglestone, Galton and Jones, 1975; Mohd Najib, 1997; Brandon *et al.*, 2008; Tay, 2010) | Content | 2a.  to relate prior knowledge and lesson | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 2b.  state the objective of the lesson | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 2c.accept or use students' ideas | Flanders, 1970; Tay, 2010 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 2d. explanation | Flanders, 1970; Tay, 2010 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 2e.  application of the concept | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | Science process skills | 2f.   Observing | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |

| | | | | |
|---|---|---|---|---|
| | | 2g. Classifying | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 2h. Measuring and Using Numbers | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 2i. Making Inferences | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 2j. Predicting | Egglestone, Galton and Jones, 1975 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 2k. Communicating | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 2l. Using Space-Time Relationship | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 2m. Interpreting data | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 2n. Defining operationally | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 2o. Controlling variables | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 2p. Making hypothesis | Egglestone, Galton and Jones, 1975 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 2q. Experimenting | Egglestone, Galton and Jones, 1975; Mohamed Najib, 1997 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | Related to students' statements | 2r. Praise/encourage/guide | Flanders, 1970; Brandon *et al.*, 2008; Tay, 2010 | |
| | | 2s.criticize/ authority justification | Flanders, 1970; Tay, 2010 | |
| | Related to students' questions | 2t. With answer | Mohamed Najib, 1997; Tay, 2010 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 2u. No answer | Brandon *et al.*, 2008; Tay, 2010 | |
| | | 2v.revert the questions to class | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | Not related to student's statement or question | 2w. Give instruction | Flanders, 1970; Egglestone, Galton and Jones, 1975; Mohamed Najib, 1997 | |
| Students' question (Flanders, 1970; Egglestone, Galton and Jones, 1975; Mohamed Najib, 1997; Brandon *et al.*, 2008; Tay, 2010) | Related to content/science process skills | 3a. to obtain/verify facts/principles/ concepts | Mohamed Najib, 1997; Egglestone, Galton and Jones, 1975; Tay, 2010 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 3b. to obtain explanation of a process | Mohamed Najib, 1997; Egglestone, Galton and Jones, 1975; Tay, 2010 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | Not related to content/science process skills | 3c. Class management | Tay, 2010 | |
| Students' statement (Flanders, 1970; Mohd Najib, 1997; Brandon *et al.*, 2008) | Related to teachers'questions or statement | 4a. with answer | Flanders, 1970; Mohamed Najib, 1997; Tay, 2010 | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |
| | | 4b. no answer | Brandon *et al.*, 2008; Tay, 2010 | |
| | Chemistry content | 4c. To give further explanation | | macroscopic |
| | | | | submicroscopic |
| | | | | symbolic |