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Malaysian Students' Scientific Argumentation: Do groups perform better than individuals?

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The practices of argumentation have recently been upheld as an important need to develop students' understanding of scientific concepts. However, the present education system in Malaysia is still largely examination-based and teacher-oriented. Thus, this study aims to examine the mastery level of scientific argumentation and its scheme among Malaysian secondary-level science students. A total of 120 students were randomly assigned to answer a Scientific Argumentation Test (SAT), either individually or in a group. Based on the answers, two groups of students, one who have answered with valid scientific concepts and another who have answered with invalid concepts, were identified and interviewed. Quantitative analysis was performed on the SAT results to determine students' mastery of scientific argumentation, and their argumentation schemes were assessed using content analysis performed on the interview transcripts. The results showed that students were weak in the construction of scientific arguments with valid concepts. Moreover, most of the constructed arguments consisted of misconceptions. The results also showed that students who were involved in group argumentation tended to have a more complex argumentation scheme, compared to individual students. As a group, students were able to argue with more scientific elements and showed their understanding of macro and submicro concepts. Hence, science teachers need to emphasize on the construction of scientific argumentation in their teaching, especially at the macro, submicro, and symbolic levels of representations, to ensure students' understanding of the concepts. This will therefore enhance their mastery of scientific argumentation and improve their content knowledge.

Keywords: *Acids and bases; Group argumentation; Individual argumentation; Scientific argumentation; Triplet relationship*

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Introduction

Argumentative practices are central to science education (Erduran, Ardac, & Guzel, 2006; Newton, Driver, & Osborne, 1999; NGSS, 2013) and have recently been upheld as a critical need for science instruction to enhance students' understanding of scientific concepts (Driver, Newton, & Osborne, 2000; Nussbaum, 2011; Sadler, 2004), to develop higher-order thinking (Eskin & Berkiroglu, 2008), to promote scientific literacy (Driver et al., 2000; Duschl & Osborne, 2002), and to eliminate misconceptions (Cross, Taasoobshirazi, Hendricks, & Hickey, 2008). However, studies have suggested that fostering productive scientific argumentation in a classroom is difficult and challenging because students often struggle with tasks that require them to present, debate, critique, and revise ideas (Jiménez-Aleixandre, Rodriguez, & Duschl, 2000; Kuhn & Udell, 2003; Osborne, Erduran, & Simon, 2004; Sadler, 2004; Sampson & Clark, 2009; Sandoval & Millwood, 2005). In addition, current literatures have mainly focused on the skills of argumentation (Dawson & Venville, 2009; Sadler, 2004; Zohar & Nemet, 2002) and the changes in the quality of the arguments constructed by students, after applying intervention in the teaching and learning of science (Clark & Sampson, 2007; Gerber, Anne, & Marek, 2001; Mason, 1998; Ross, Fisher, & Frey, 2009; Sampson & Clark, 2009). Very few studies have examined the presence of argumentation elements and the validity of arguments constructed by students. Thus, this study aims to examine the mastery of scientific argumentation and compare students' scientific argumentation in individual and group settings. More specifically, this study focuses on content-specific scientific argumentation related to the triplet relationship in chemistry, namely the macro, submicro, and symbolic levels of representations (Gilbert & Treagust, 2009).

Scientific Argumentation in Malaysian Science Education

The main goal of science education is to prepare students to be scientifically literate (NRC, 1996). The inquiry approach, which is student-centred, is key to increase student's scientific literacy by developing their scientific argumentation capability (Duschl & Osborne, 2002; Zembal-Saul, 2009). According to Erduran et al. (2006), the emphasis on scientific argumentation has become the major objective in the teaching and learning of science. This emphasis has shifted the attention of science as an experimental verification process to science as a scientific argumentation and explanation process (Kuhn, 1993; Zembal-Saul, 2009). Science education no longer focuses on conceptual repetition or factual accumulation, but focuses on the construction of knowledge through scientific argumentation (Braaten & Windschitl, 2011; Cavagnetto, 2010; Erduran et al., 2006). Thus, the mastery of scientific argumentation is considered as the core of reasoning abilities and academic achievements.

In Malaysia, the Ministry of Education has long emphasized on thinking habits among students through the practice of higher-order thinking skills, where the science curriculum has implicitly promoted argumentation skills through the adoption of reasoning skills. However, the present education system is still largely examination-based and teacher-oriented, and very little attention is given to scientific argumentation (Heng & Johari, 2013; Hong & George, 2011). According to local studies (Heng & Johari, 2013; Mohd Ali & Shaharom, 2003), the teaching and learning of science had heavily emphasized on teacher exposition, where students tend to be passive learners. Science lessons generally start with the teacher introducing a topic, examining previous topics, explaining the contents, and giving instructions on activities to be undertaken. It is noted that the explanation of contents normally lacks any emphasis on the linkage between the macro, submicro, and symbolic representations. Students would then carry out activities such as answering questions, conducting experiments, and recording observations, in accordance with the instructions provided (Heng & Johari, 2013). Lastly, the lesson would end with the discussion of answers, cleaning of apparatus, and noting down of homework. As a result, very little time is spent on discussing the scientific ideas and interpreting the findings of an experiment. In addition, science teachers mainly focus on asking close-ended questions, before providing explanations and answers, while students mainly listen and respond to questions, based on reference materials (Tay & Mohammad Yusof, 2008). Moreover, argumentative activities such as presentations, debates, and question–answer sessions are rarely conducted in secondary-level science classes (Heng & Johari, 2013). This type of instructional approach trains students to memorize scientific facts (Hong & George, 2011) and does not assist with their development of scientific argumentation skills. This also affects their ability to master scientific argumentation.

Current literature related to argumentation mainly showed that students from all levels of education have problems mastering scientific argumentation (Dawson & Venville, 2009; Heng, Johari, & Yazid, 2012; Nurul, Zaidatun, & Nurbiha, 2009; Zohar & Nemet, 2002). Studies in Malaysia also indicated that the mastery level of scientific argumentation is not satisfactory among tertiary science education students (Heng et al., 2012) and secondary-level students (Foong & Daniel, 2010). These studies showed that students have difficulty in justifying their claims or answering using appropriate scientific explanations (Mohd Ali, Salmiza, Zurida, & Ahmad Nurulazam, 2003). Besides, students often construct simple arguments that are only composed of a claim and data; students were weak in presenting scientific argumentation elements such as warrant, backing, and qualifier (Heng et al., 2012). This may be due to the lack of experience and exposure to scientific argumentative activities in science classes (Heng & Johari, 2013; Newton et al., 1999), the lack of scientific knowledge (Foong & Daniel, 2010; Sampson & Clark, 2011), and the existence of misconceptions (Cetingul & Geban, 2005).

Most studies have used Toulmin's Argumentation Pattern (TAP) (Toulmin, Rieke, & Janik, 1979) to assess the arguments constructed by students (Bell & Linn, 2000; Dawson & Venville, 2009; Driver et al., 2000; Erduran, Simon, & Osborne, 2004; Evagorou, Jimenez-Aleixandre, & Osborne, 2012; Jiménez-Aleixandre et al., 2000; McNeill & Pimentel, 2010; Osborne et al., 2004). According to TAP, an argument consists of six elements: *claims* are conclusions, propositions, or assertions; *data* are the foundations for the claims; w*arrants* are explanations of the relationships between data and the claim; *backings* are basic assumptions to strengthen the warrants; *rebuttals* indicate statements that specify the conditions under which the claim will not be true; and *qualifiers* provide conditions under which the claim is true. In this study, data specifically refer to the evidences that support the claims (Simon, Erduran, & Osborne, 2006; Venville & Dawson, 2010). Simple arguments generally contain the elements of claim, data, warrant, and backing, whereas complex arguments would also include qualifiers and rebuttals. However, TAP does not consider the validity of scientific knowledge demonstrated in students' arguments (Sampson & Clark, 2008). Furthermore, studies have shown that students' arguments often incorporate inaccurate or irrelevant scientific ideas (Zohar & Nemet, 2002), even though the arguments are relatively sophisticated from a structural perspective (Sampson & Clark, 2008). Because scientific argumentation is viewed as a core aspect in knowledge construction, when engaging in scientific argumentation, students need to propose, support, criticize, evaluate, and refine ideas about scientific subjects (Newton et al., 1999) and use scientific theories and evidences to confirm their claim. Hence, the content of the argument is important to improve students' understanding of the concepts being studied. Besides, the existence of misconceptions during the construction of scientific arguments also acts as a barrier to learning (Cetingul & Geban, 2005). In order to provide a holistic overview of students' scientific argumentation, this study emphasizes on both argumentation structure and the validity of the content knowledge articulated in students' arguments.

Individual and Group Argumentations

A student's involvement in scientific argumentation, whether individually or in a group, provides experience and awareness to the theoretical development process. According to Schwarz, Neuman, and Ilya (2003), student-centred activities, based on argumentation, are critical components in the development of scientific knowledge. Many researchers also stated that a classroom environment that encourages student's participation, in the class or in a small group, is important to foster the development of scientific argumentation skills (Chin & Osborne, 2010). Research indicated that group argumentative activities could promote students' scientific argumentation, due to the influence of participating group members (Erduran et al., 2006; McNeill & Martin, 2011; Schwarz et al., 2003). In groups, students are more likely to consider new or conflicting information that they have previously disregarded, as they begin to evaluate and value their peers' viewpoints. In addition, collaborative reasoning and arguing through group argumentation encourage the co-construction of knowledge and conceptual understanding (Asterhan & Schwarz, 2009; Mason, 2001), and promote thinking skills (Fencl, 2010; Mason, 2001). Besides that, research also showed that group activities could instil responsibility among group members to achieve the objective of the activities (Nurzatulshima, Lilia, Kamisah, & Subahan, 2009).

There are also researches that combined group discussions with individual writing assignments. Their findings showed that such combination increases scientific argumentation skills (Fencl, 2010; McNeill & Martin, 2011). However, in another study, Sampson and Clark (2009) reported that working in groups do not necessarily produce better scientific arguments than when working alone. In addition, researchers also showed that interactions and collaborations among group members may not always be valuable and could act as a barrier to a productive outcome (Osborne et al., 2004). Hence, the exact outcome of a student working in groups or individually remains unresolved. Moreover, very few studies have explicitly compared individual and group performances in terms of content-specific scientific argumentation. Thus, the aim of this study is to examine students' mastery of scientific argumentation, when engaged in individual and group argumentations. More specifically, we investigate this in the context of Malaysian secondary science education, where the triplet relationship in chemistry, namely the macro, submicro, and symbolic representations, are considered. The consideration of the three levels of representations would allow students to evaluate the concepts being studied and thus, construct a better argument, in terms of the argumentation content. It is noted that the submicro representation needs to be knitted into the observable macro and symbolic levels to enhance students' understanding of chemistry concept (Bucat & Mocerino, 2009; Johnstone, 2000).

Purpose and Research Questions

The purpose of this study is to compare the mastery of scientific argumentation, based on the accuracy of the scientific concepts and the presence of scientific argumentation elements between students involved in individual argumentation and group argumentation. More specifically, the research questions are:

(1) What is the difference in the mastery of scientific argumentation between students engaged in individual argumentation and group argumentation?
(2) What is the difference in the mastery of scientific argumentation elements, based on TAP, between students engaged in individual argumentation and group argumentation?
(3) What is the difference in the scientific argumentation scheme between students engaged in individual argumentation and group argumentation?

Research Methods

The study conducted was a combination of quantitative and qualitative descriptive research. The quantitative component focused on the mastery of scientific argumentation, determined based on the validity of the chemistry concepts and the presence of argumentation elements in students' written tests. The qualitative component focused on students' scientific argumentation scheme, where a detailed analysis of the written tests and transcripts obtained from students' interviews was performed. The argumentation scheme was determined based on the argumentation structure, the validity of the argument, and the triplet relationship in the chemistry concepts.

The schools in which the study was conducted are located in the south of peninsular Malaysia. The study was carried out in the students' most natural setting to enable a true evaluation of their argumentation skills, cultivated through the secondary level Chemistry curriculum. As the curriculum had implicitly promoted argumentation skills through the adoption of reasoning skills, in this study, no intervention was introduced to explicitly promote scientific argumentation. As such, the data collected were useful to determine students' mastery of scientific argumentation and the types of arguments they would naturally use when answering scientific questions.

To assess students' mastery of scientific argumentation, participants were first randomly assigned to complete a Scientific Argumentation Test (SAT), either individually or in a group. An example of the SAT is included in Appendix A. Students assigned to individual argumentation worked alone whereas students assigned to group argumentation worked in groups of four. Based on the SAT, students are further divided into two groups, one where students have constructed arguments with valid chemistry concepts, and the other where students have constructed arguments that are irrelevant, illogical, or with invalid concepts. Interviews are then conducted on both groups, and the interviews were audio-taped, transcribed, and analysed.

Content Area

The SAT focused on three sub-concepts of acids and bases: neutralization, properties of acids and bases, and the strengths of acids and bases. The concept of acids and bases was chosen in this study, owing to the fact that this concept has been taught to students since lower secondary in Malaysia and nonetheless, it is also a basic and important concept in the learning of other chemistry concepts, such as chemical equations and chemical reactions (Demircioglu, Ayas, & Demircioglu, 2005). Furthermore, many studies in Malaysia and other countries have shown that students generally have misconceptions in their learning of acids and bases (Abu Hassan & Tan, 2009; Bayrak & Bayram, 2010; Heng, Johari, & Seng, 2013; Sendur, Ozbayrak, & Uyulgan, 2010; Tarhan & Sesen, 2010). In the SAT, each sub-concept was presented with a scenario and data, followed by six questions that encapsulate the six elements of argumentation, as suggested in the TAP.

Participants

This study involved 120 ($n = 120$) 16-year-old fourth form science students, chosen from four randomly selected schools in the district of Pasir Gudang, Johor, Malaysia. The selected students, with a gender breakdown of 51.67% female and 48.33% male, were enrolled in Chemistry. Although the students in schools A ($n = 38$), B ($n = 30$), C ($n = 28$), and D ($n = 24$) were taught by four different teachers, each teacher would have followed the same national curriculum using the same instructional materials.

Procedure

All the participants were randomly divided into two groups to answer the SAT. 60 participants were involved in individual argumentation, answering the SAT without any discussion, while 15 groups of four participants ($15 \times 4 = 60$) were involved in group argumentation. According to Laughlin, Hatch, Silver, and Boh (2006), the comparison of group versus individual performances can be conducted by comparing *n* groups of size *s* with an equivalent number of ($n \times s$) individuals. Thus, the average performance of the individual can then be compared to the average performance of the groups.

Participants in both categories were given some instructions before answering the SAT. They were specifically told that for each question, they should state the answers using scientific data, relate the data with claims, and, where appropriate, explain their answers using scientific theories and facts, and provide conditions under which the claim is true or the claim will not be true. In addition, students who were involved in group argumentation were also asked to argue and support their own answers with scientific justifications to reach a consensus. After completing the SAT within the allocated time, the answers provided were used to distinguish between participants who constructed arguments with valid or invalid concepts. Participants who have constructed illogical or irrelevant arguments were also grouped as those with invalid concepts.

To identify the scientific argumentation scheme of the students who mastered the scientific concepts and of students with misconceptions, eight students from individual argumentation and five groups (20 students) from group argumentation were selected using purposeful sampling method for semi-structured interviews. In addition to their answers in the SAT, questions such as 'How do you know?', 'What is your evidence?', 'What were your reasons for … .?', 'How sure are you that your answer is correct?', and 'If your friends disagree with your answer and said that the other solution is the correct answer, will you agree with them?' were asked in the interview. The last two questions were used to determine the students' confidence level, related to the arguments constructed. In the event that the students changed their answers after the two questions, it was noted that they were not confident with their answers.

Data Collection and Analysis

Data analysis in this study was conducted based on TAP because its terminology and structure provides a basis for the identification of scientific argumentation elements and argumentation schemes in students' arguments. After collating the SAT answers and performing content analysis (Corbin & Strauss, 2008) on the transcripts of the semi-structured interviews, students' mastery level and scientific argumentation scheme were determined. Analysis of students' mastery of scientific argumentation was based on the validity of chemistry concepts and the presence of articulation of scientific argumentation elements. The method to assess students' arguments is shown in Appendix B. First, students' arguments were examined. If the arguments consisted of any misconceptions or was illogical or irrelevant, that argument was grouped as argument with invalid concepts. Alternatively, any argument that was conceptually correct and without any ambiguities was grouped as argument with valid concepts. Next, the same arguments were examined to identify the presence of scientific argumentation elements. Students' responses to the argumentation tests were coded based on a rubric, which was designed to assess argumentation quality. The rubric is provided in Appendix C. After the grouping and coding, the number of arguments with valid and invalid concepts and the number of scientific argumentation elements constructed by students in both individual and group argumentations were also presented as a percentage. The findings reflected the students' ability to present content-specific scientific argumentation and their scientific argumentation skills.

Results and Discussion

This section is divided into three subsections, based on the research questions. Each subsection includes the results of the analysis and a discussion of the findings.

Mastery of Scientific Argumentation between Individual and Group Argumentations

The results in Table 1 show that students' mastery of scientific argumentation on the concepts of acids and bases was weak in both individual and group argumentations; overall, less than 10% of arguments constructed had valid concepts. This finding agreed with many studies that indicated students' achievement in these concepts was not satisfactory (Sesen & Tarhan, 2010) and students often struggled with scientific argumentation (Jiménez-Aleixandre et al., 2000; McNeill, Lizotte, Krajcik, & Marx, 2006; Osborne et al., 2004). Most students constructed arguments that consisted of misconceptions, were illogical or irrelevant, and had unsupportive reasons or ambiguities (Choi, Notebaert, Diaz, & Hand, 2010). It seems that misconception is the most serious difficulty faced by fourth form students when constructing scientific arguments. This finding is consistent with the result by Ozmen and Yildirim (2005) who reported that students at all levels had common misconceptions about the concepts of acids and bases.

Table 1. Percentage of arguments constructed by students in three different sub-concepts

	Neutralization (%)		Strength of acids and bases (%)		Properties of acids and bases (%)	
Argumentation condition	Argument with valid concepts	Argument with invalid concepts	Argument with valid concepts	Argument with invalid concepts	Argument with valid concepts	Argument with invalid concepts
Individual	8.61	91.39	3.06	96.94	3.89	96.11
Group	14.44	85.56	8.89	91.11	7.78	92.22

The study also showed that students often used their personal views to generate claims, rather than using the data provided in the task given (Hogan & Maglienti, 2001). This may be due to the lack of understanding of the goals and processes of scientific argumentation (Sampson & Clark, 2009) and the poor exposure to scientific argumentative activities in schools (Heng & Johari, 2013; Newton et al., 1999). As pointed out by Sampson and Clark (2009), students must first make sense of the phenomenon they are studying. However, such practice may be difficult and challenging for students causing them to simply support their arguments with intuitive knowledge.

As for the comparison between individual and group argumentations, the results showed that groups outperformed individuals on all three sub-concepts. This result aligned with findings which demonstrated that groups tend to perform better than individuals on a task that is complex or focuses on conceptual issues (Barron, 2000) and that group activities can enhance students' scientific argumentation (Erduran et al., 2006; McNeill & Martin, 2011; Schwarz et al., 2003). This is because students are involved in the pooling of knowledge, combining of different ideas, integrating different cognitive strengths, improving error correction, and monitoring capabilities (Sampson & Clark, 2009). The process of sharing cognition through reasoning and arguing promote the generation of scientific arguments with valid concepts (Mason, 1998). Conversely, students involved in individual argumentation did not have the opportunity to engage in interacting and sharing ideas with others.

In terms of students' mastery of scientific argumentation related to the three sub-concepts being studied, results showed that the mastery of neutralization was better compared to the strengths or properties of acids and bases, as reported in our previous studies (Heng et al., 2012; Heng et al., 2013).

Mastery of Scientific Argumentation Elements between Individual and Group Argumentations

Analysis of the arguments constructed by students also showed that students were very weak in the mastery of scientific argumentation elements. As shown in Table 2, less than 30% of arguments constructed by students had argumentation

Table 2. Percentage of argumentation elements constructed by students

	Individual argumentation (%)		Group argumentation (%)	
Element	Element with valid concepts	Element with invalid concepts	Element with valid concepts	Element with invalid concepts
Claim	17.22	82.78	28.89	71.11
Data	8.89	91.11	13.33	86.67
Warrant	2.22	97.78	8.89	91.11
Backing	0.56	99.44	4.44	95.56
Qualifier	2.22	97.78	4.44	95.56
Rebuttal	0.00	100	2.22	97.78

elements with valid concepts. This indicated that students have difficulties and often struggle in constructing scientific arguments, which is similar to the observations by Dawson and Venville (2009), Jiménez-Aleixandre et al. (2000), Osborne et al. (2004), and Zohar and Nemet (2002). According to Table 2, students in group argumentation performed better than students in individual argumentation for all the elements. This showed that collaborative development of explanation and justification in group argumentation advances students' conceptual understanding and thus lead them to the construction of better argumentation elements.

Data in Table 2 indicate that the usage of the element *claim* was the highest among students, followed by the element data. Results also showed that the mastery level of other elements, such as *warrant*, *backing*, *qualifier*, and *rebuttal*, was very weak for both individual and group argumentations. This shows that students were only constructing simple arguments that consist of a claim and data, which corroborate with the study by Heng et al. (2012). Furthermore, such results also reaffirmed the findings whereby students are not able to justify their explanations using appropriate data (Sadler, 2004), encounter difficulties differentiating between what is relevant and irrelevant, do not provide warrants or reasoning (McNeill & Krajcik, 2007), do not include backings to the warrants (Bell & Linn, 2000), and do not use scientific knowledge to support their decisions (Zohar & Nemet, 2002).

Scientific Argumentation Scheme between Individual and Group Argumentations

Students' scientific argumentation schemes were determined from the SAT and the interview transcripts. Arguments which consisted of claims with valid concepts were categorized as scientific argumentation whereas arguments with misconceptions, were illogical or irrelevant were grouped as non-scientific argumentation. Based on the data collected, four schemes of students' argumentation were identified.

(a) Scientific Argumentation Scheme in Individual and Group Argumentations. In this study, the findings showed that a group's scientific argumentation scheme consisted of more argumentation elements and was more complex compared to an individual's argumentation scheme, and nonetheless contained less misconceptions. As shown in Figure 1, a group's scientific argumentation scheme consisted of a claim that was constructed based on the data and supported by warrants and backings at mostly macro and some submicro levels, whereas an individual's scientific argumentation scheme (Figure 2) only consisted of a claim which was based on single data and supported by warrant and backing at the macro level with misconceptions. This showed that students possessed some content knowledge, but can only use macro level and could rarely transform to submicro or symbolic levels (Kozma & Russell, 1997). Thus, they lacked the ability to provide suitable explanations (Sia, Treagust, & Chandrasegaran, 2012). These findings also corroborated the study by Barron (2000) and Mason (1998) which reported that group performance is much better than individual performance, especially for complex assignments as group argumentations make

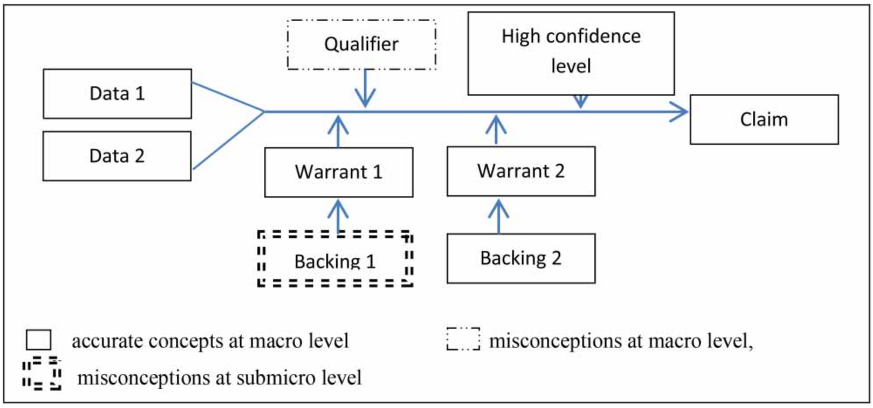

Figure 1. Scientific argumentation scheme by students engaging in group argumentation

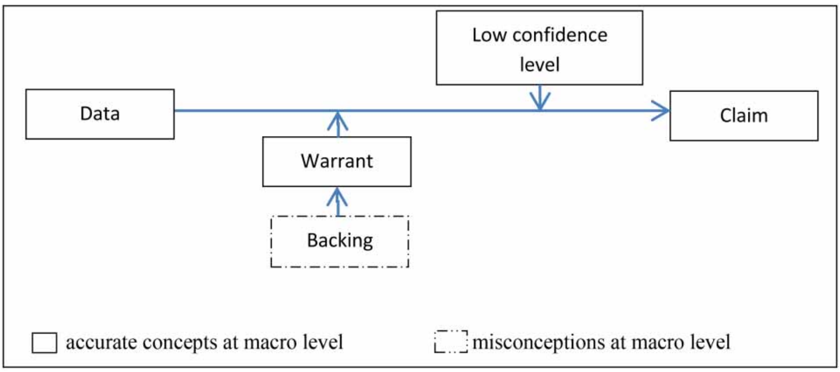

Figure 2. Scientific argumentation scheme by students engaging in individual argumentation

argument generation a social as well as a cognitive activity (Venville & Dawson, 2010). Furthermore, 83.33% and 25.00% of students who were involved in group argumentation and individual argumentation, respectively, were confident with their constructed arguments. The result indicated that students in group argumentation have a higher confidence level than students in individual argumentation. This is because students who were involved in group argumentation have opportunities to share ideas, detect and correct each other's mistakes, explain ideas, and listen to each other's explanations. This process has resulted in a better understanding of the macro and submicro levels and has further increased the confidence level and the outcome of the group's scientific argumentation. Furthermore, prompts and refutations in groups allow students to be aware of their weaknesses in their own arguments (Foong & Daniel, 2013).

In addition, students in both argumentation conditions did not generate scientific qualifier and rebuttal, which symbolize higher cognitive skill (von Aufschnaiter, Erduran, Osborne, & Simon, 2008). This showed that students could only generate simple arguments, which aligns with the findings by Heng et al. (2012). Most students in group argumentation understood the strength and limitation of the claim they generated. They even emphasized that they were *very sure my solution is correct*. However, they could not provide conditions under which the claim is true (qualifier) and a statement that specifies the conditions when the claim is not be true (rebuttal). This is due to the lack of experience and knowledge about the structure of argumentation. As the teaching and learning of science in school generally focuses on teacher- and exam-oriented activities, they do not encourage the development of students' scientific argumentation (Heng & Johari, 2013; Newton et al., 1999). In addition, students in both groups also indicated that they would refer their teachers to increase the level of confidence of their arguments. The underlying factors that contributed to this may include students' conception that treat scientific knowledge as factual information when sourced from an authority (Bucat & Mocerino, 2009; Chin, 2007; Driver et al., 2000), as well as the Malaysian culture where students tend to fully obey the instructions of teachers (Heng & Johari, 2013).

Figure 3 shows an example of group X's scientific argumentation scheme. It can be observed that the argument constructed by group X consisted of claims, data, warrants, backings, and qualifiers. Although the argument can be categorized as a

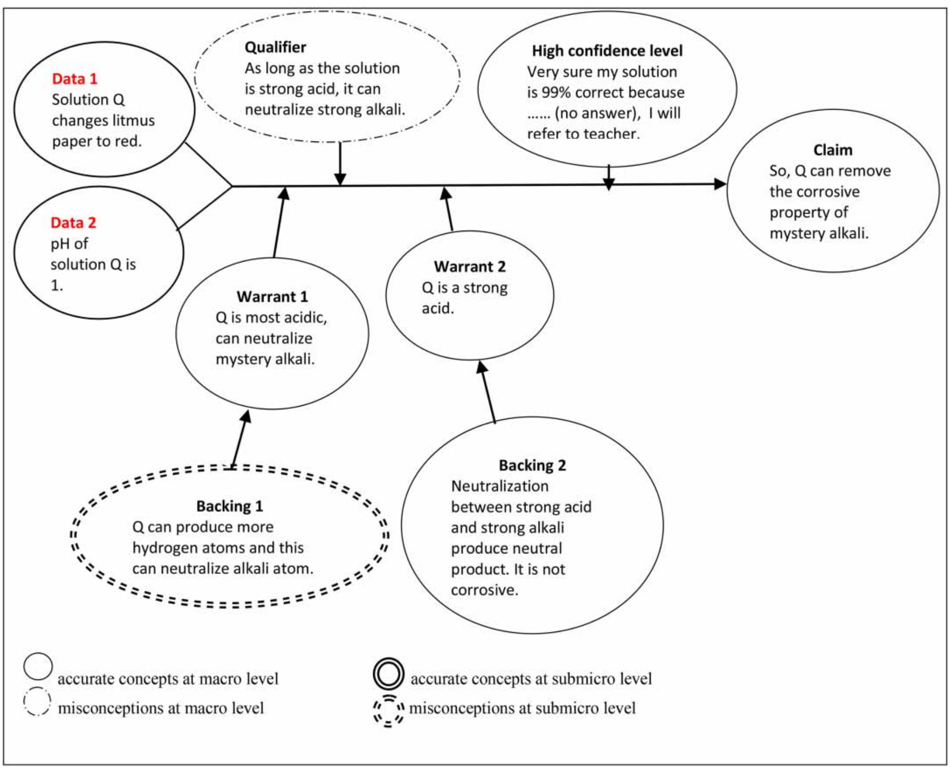

Figure 3. Example of group X students' scientific argumentation scheme regarding neutralization concept

simple argument due to the absence of rebuttal and the presence of misconceptions in qualifier (Toulmin et al., 1979), the argument provided many justifications to the claim constructed. This observation suggested that, in groups, students get to combine different ideas and explain ideas to answer questions and correct mistakes (Sampson & Clark, 2009), which enhances the quality of the argument constructed. Besides that, group argumentation also increased students' confidence level. In terms of accuracy, most of the scientific concepts at the macro level were accurate. However, misconceptions did exist at the submicro level. This showed that students might rote-learn content knowledge and hence were not able to give deeper justifications (Cheng & Gilbert, 2009), especially at the submicro level. These findings corroborated the study by Smith and Metz (1996), which reported that many first-year undergraduates were able to define 'strong acid' but faced difficulties in choosing a diagram that represented the submicro level of hydrochloric acid. Similar findings were also reported by Devetak, Vogrinc, and Glazar (2009), where students' understanding of dissolving solid substances at submicro level was weak and consisted of misconceptions. This might be due to the students' poor understanding of the nature of particles (Kozma & Russell, 1997). Besides, teachers did not use all the three levels of representations and the linkage between each level during instruction, causing students to learn chemistry concepts at the three levels separately in a discrete manner (Treagust, Chittleborough, & Mamiala, 2003). As a result, they may not have a thorough understanding and may have inaccurate perception of the chemical phenomena (Jaber & BouJaoude, 2012). Hence, chemistry teachers should emphasize on the construction of scientific argumentation and the linkage between the three levels of representations to ensure deeper understanding of chemistry concepts and thus enhance content knowledge and the mastery of scientific argumentation.

(b) Non-scientific Argumentation Scheme in Individual and Group Argumentations. Figure 4 shows the argumentation scheme of students involved in individual argumentation who had constructed arguments with invalid concepts. As can be observed from Figure 4, individual students' non-scientific argumentation

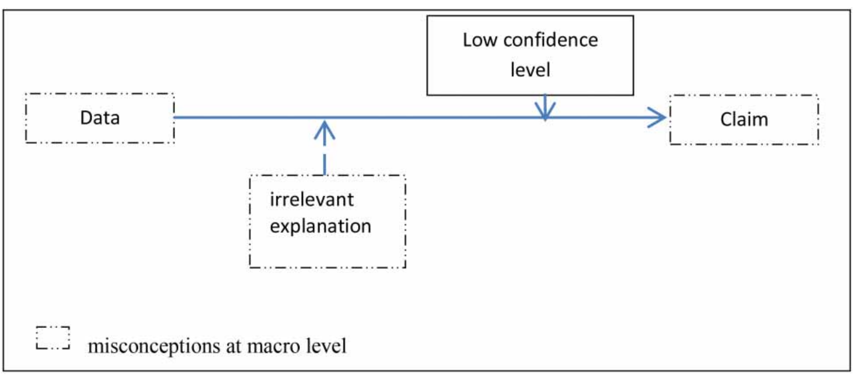

Figure 4. Non-scientific argumentation scheme by students engaging in individual argumentation

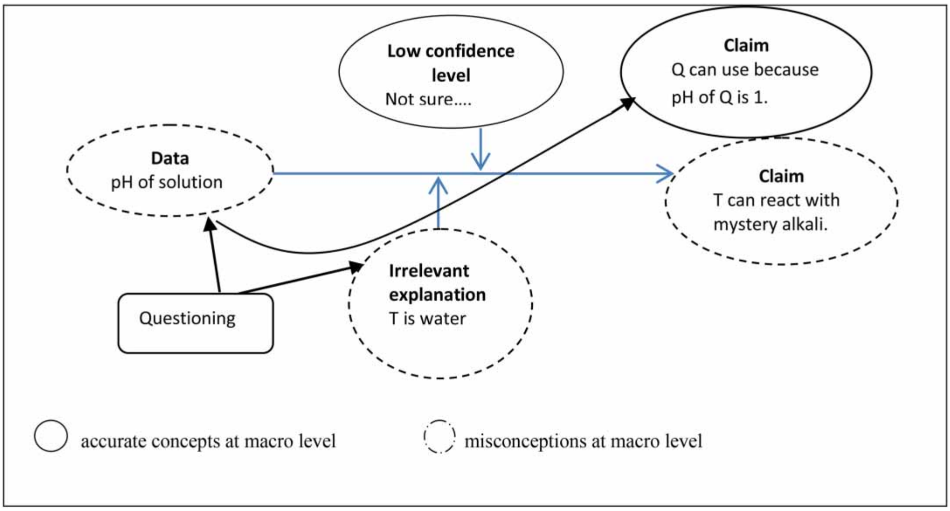

Figure 5. Example of individual student Y's non-scientific argumentation scheme

scheme was simple and only consisted of incorrect data, claim, and irrelevant explanations. Furthermore, all students (100%) were not confident with their constructed argument, which indicated the limitation of content knowledge (Bowen & Roth, 1999). As a result, students tend to change their claims when prompted by the interviewer, as shown in Figure 5.

Figure 5 showed that student Y relied on his personal views and lacked content knowledge when constructing arguments (Foong & Daniel, 2010; Hogan & Maglienti, 2001). Besides, the students were highly dependent on their teacher to gain confidence against the argument constructed. This again showed that students' scientific belief is sourced from an authority, similar to the observations from group argumentation. However, group argumentation students had more complex argumentation schemes, as shown in Figure 6.

According to Figure 6, students in group argumentation were able to support their claim with warrants, backing, and qualifiers at the macro level. This again indicated that collaboration between group members foster the generation of more complex argument (Sampson & Clark, 2009); albeit the argument consisting of inaccurate concepts. Besides, students had high level of confidence (75%) against the argument constructed. However, high level of confidence against inaccurate answers indicated strong misconceptions held by students (Saglam, 2010). An example of group Z's misconception about neutralization concepts is shown in Figure 7.

This interesting finding showed that this group of students thought that when the total pH of a mix solution equals 14, the solution will become neutral. These findings are in line with several studies which reported that students have misconceptions in the concepts of acids and bases (Bayrak & Bayram, 2010; Demircioglu et al., 2005; Ozmen & Yildirim, 2005; Tarhan & Sesen, 2010). Besides misconceptions, Figure 7 also shows that group Z lacked scientific concepts and were not able to

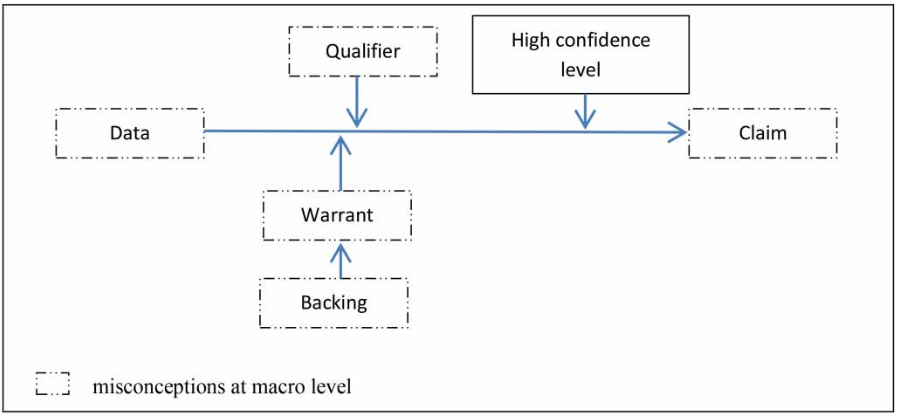

Figure 6. Non-scientific argumentation scheme by students engaging in group argumentation

- Solution P, Q and R can be used to remove (the corrosive property of) the mystery alkali.
- pH for P is 5, Q is 1 and S is 8.
- (5 + 1 + 8 = 14). The total pH is 14, so it becomes neutral and no corrosive property.
- I am sure because ….. (no answer).

Figure 7. Example of group Z students' answer

provide a deeper explanation at the submicro level. This causes an unstable, disorganized, and ambiguous argumentation scheme (Ausubel, 1963). However, the use of prompts and refutations at the submicro level during group interview showed that students' misconceptions can be removed and replaced by accurate scientific concepts. Thus, scientific argumentation especially in group setting can be used as a tool for conceptual change (Aydeniz, Pabuccu, Cetin, & Kaya, 2012; Nussbaum, 2011) and to eliminate misconceptions (Cross et al., 2008).

Conclusion and Research Implications

Scientific argumentation has recently been upheld as a critical need for science instruction, due to the fact that it is able to enhance students' understanding of scientific concepts and promote students' reasoning skills in a specific domain. However, studies have shown that students often struggle in generating scientific arguments that show their understanding of scientific knowledge. Thus, this study investigated the mastery of scientific argumentation among fourth form science students in Malaysia, based on validity, triplet relationship, and the presence or absence of scientific argumentation elements in chemistry concepts.

The findings showed that students in group argumentation performed better than students engaged in individual argumentation, which aligns with the results of many studies. However, regardless of individual or group, the mastery of scientific argumentation for all students was not satisfactory. This is due to the poor understanding of scientific concepts and the lack of understanding of the goals and processes of scientific argumentation. This result indicated that the Malaysian science curriculum has not accorded sufficient emphasis to scientific argumentation, and implied that the teaching and learning of science, especially Chemistry, need to improve by explicitly emphasizing on scientific argumentation.

In terms of the mastery of scientific argumentation elements, students involved in group argumentation outperformed students involved in individual argumentation. The results suggested that collaboration during group argumentation plays an important role in the construction of scientific arguments. Therefore, group argumentative activities need to be given priority in the teaching and learning of science. Science teachers need to create a collaborative atmosphere, where discussion, questioning, evaluation, and criticism are the mode, rather than the exception (Mason, 1996). Moreover, the overall results indicated that most of the arguments constructed were simple arguments that only consisted of a claim and data. Students in both argumentation conditions were not able to construct arguments with scientific qualifiers and rebuttals which corroborates our previous study (Heng et al., 2012). This finding suggested that there is a need to scaffold students on how to construct a fruitful scientific argument if argumentation is used as a method of promoting conceptual understanding (Sandoval & Millwood, 2005).

As for the students' argumentation scheme, the findings showed that students involved in group argumentation can construct more complex arguments, which consisted of macro and some submicro level concepts, and with less misconceptions. This suggested that cognitive sharing in group argumentation stimulates students to think deeply at the three levels of representations, which promotes knowledge construction (Mason, 1998) and improves argument quality. It was also noted that students' misconception can be reduced and replaced with accurate scientific concepts through prompts and refutations in scientific argumentation. Since students often need to refer to their teachers to gain assurance against the arguments constructed, teachers can engage students in group argumentative discourse to allow them to reflect and be aware of their own ideas, to address misconceptions, and to develop a better understanding.

All in all, this study suggested that Malaysian fourth form science students' mastery of scientific argumentation was weak and students engaged in group argumentation performed better than students engaged in individual argumentation, in terms of argumentation elements and the quality of the arguments. The problem of misconception, the lack of understanding of the triplet relationship, and the lack of theoretical understanding of argumentation structure have contributed to the students' poor performance. Therefore, students need to be involved in scientific argumentative tasks that provide opportunities to collaborate with peers and be taught explicitly the elements of scientific argumentation. Besides, science teachers also need to incorporate the linkage between the macro, submicro, and symbolic representations during instruction (Tsai, 1999; Wu, 2003) to ensure a better understanding of scientific concepts (Jaber & BouJaoude, 2012), to eliminate misconceptions (Russel et al., 1997), and to enhance students' scientific argumentation.

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Appendix A. Scientific argumentation test

A – Mystery Alkali Solution (Neutralization)

During an investigation in a dilapidated house, your friend and you were trapped in the cellar. In front of the door, there is a solution bottle labelled 'strong mystery alkali'. There were also five other solutions P, Q, R, S, and T located in a box. Your friend and yourself tried to escape but were stopped by the 'strong mystery alkali' solution, which was placed in front of the door (Figure A1). To save yourself, you need to remove the strong corrosive property of the mystery alkali solution. You received information that one of the solutions P, Q, R, S, and T has the potential to remove the strong corrosive property of the mystery alkali solution. Your friend and you have carried out several tests on the solutions P, Q, R, S, and T, and Table A.1 shows the data you collected.

Figure A1: Situation in the cellar

Table A1. Collected data

Solution	pH	Reaction with metal	Reaction with carbonate	Colour of blue litmus paper	Colour of phenolphthalein
P	5	Hydrogen gas is produced	Carbon dioxide gas is produced	Red	Colourless
Q	1	Hydrogen gas is produced	Carbon dioxide gas is produced	Red	Colourless
R	13	No changes	No changes	No changes	Pink
S	8	No changes	No changes	No changes	Pink
T	7	No changes	No changes	No changes	Colourless

Questions:

1. What is the *conclusion* that you can draw from the data collected to solve your problem?

2. What *data* are you using to support your conclusion? Explain your answer.

3. Explain how you *linked* these data as a support for your conclusion.

4. How do you explain that the *relationship* between the data and your conclusion (answer in no. 3) is *reliable/accurate*?

5. Your friend is in doubt over your conclusion. *How sure are you* that your conclusion is correct in all conditions? Give *reasons* or conditions that support your answer.

6. State if there are other *conditions* which you think *may affect your conclusion* or may cause your conclusion to be inaccurate? Explain your answer.

Appendix B

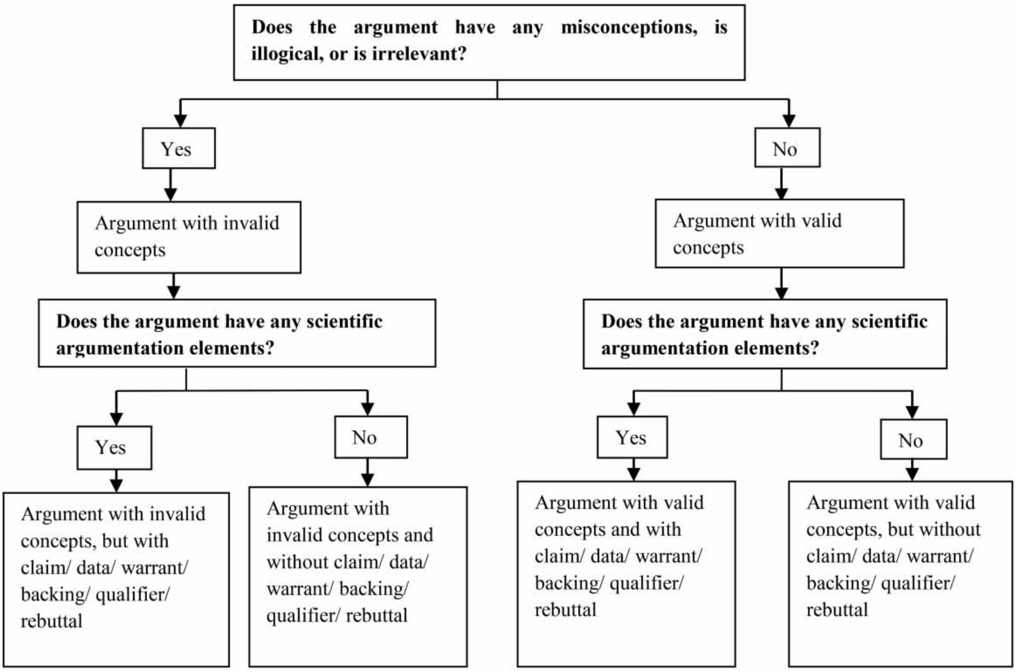

Figure B1: Method to assess students' arguments

Appendix C

Table C1: SAT Rubric

Scientific argumentation element	Element with invalid concepts	Element with valid concepts
1. Claims	No conclusion, proposition, or assertion given or the conclusion, proposition, or assertion given has misconceptions	Conclusion, proposition, or assertion given is related to the phenomenon with correct scientific concepts
2. Data	No evidence given or evidence given is not related to support the claim constructed or has misconceptions	Evidence given supports the claim constructed with correct scientific concepts
3. Warrant	No explanation of the relationship between data and claim given or explanation given has misconceptions	Explanation given clearly shows the relationship between data and claim with correct scientific concepts

(*Continued*)

Table C1: Continued

Scientific argumentation element	Element with invalid concepts	Element with valid concepts
4. Backing	No basic assumption or no further information to strengthen the warrant was given or the assumption given has misconceptions	Basic assumptions or some further information was given to strengthen the warrants with correct scientific concepts
5. Qualifier	No condition under which the claim is true was stated or the condition given has misconceptions	Condition under which the claim is true with correct scientific concepts was stated
6. Rebuttal	No statement that specifies the conditions when the claim will not be true was stated or the statement given has misconceptions	Statement that specifies the conditions when the claim will not be true with correct scientific concepts was stated