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SCIENTIFIC ARGUMENTATION AND THE PROMOTION OF CONCEPTUAL CHANGES

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Argumentative practices are central to science education due to their ability to foster students' understanding of scientific concepts, and to eliminate alternative frameworks. In addition, conceptual changes are likely to occur when deeper cognitive processing is required, especially when students are asked to clarify, explain, and defend their own ideas. Thus, this study aims to examine conceptual changes in the context of scientific argumentation, based on the triplet relationship in chemistry. Students are first asked to answer an Open-ended Scientific Argumentation Test 1 (OSAT 1). Based on the arguments constructed, 32 students are selected using purposive sampling to complete the OSAT 2 in a guided group argumentation setting. Discussions during the guided group argumentations are also recorded. Data are then analysed using content analysis technique to identify the process of conceptual changes. The findings of this study show that almost all of the students change their existing alternative frameworks to the correct scientific concepts after being involved in a guided group argumentation process. This study also shows that the process of deep thinking between two alternative concepts leads to conceptual changes, which helps students in constructing complex arguments that linked between the macroscopic, sub-microscopic, and symbolic levels of the triplet relationship. Hence, the teaching and learning of science need to emphasize on guided group argumentations to eliminate alternative frameworks and to promote conceptual changes.

***Keywords*:** Acids and bases, alternative frameworks, conceptual changes, group argumentations, triplet relationship

INTRODUCTION

Argumentative practices are central to science education (Erduran *et al.,* 2006; Marttunen, 1994; Newton *et al*., 1999) and have been greatly emphasized in the National Science Standard (American Association for the Advancement of Science, 1993; National Science Education Standards, 1996). Argumentation in science is viewed as a knowledge building and validating practice, where individuals propose, support, critique and refine ideas, in an effort to understand the natural world (Driver *et al.,* 2000; Kuhn, 1993). Current literature indicates that scientific argumentative activities can promote student's understanding of scientific concepts (Driver *et al*., 2000; Nussbaum, 2011; Sadler, 2004; von Aufschnaiters *et al*., 2008; Zohar and Nemet, 2002), and eliminate alternative frameworks (Cross *et al*., 2008). The involvement of students in argumentative activities also enhances their scientific

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reasoning skills (Osborne *et al*., 2004) and nurture conceptual changes (Nussbaum and Sinatra, 2003; Nussbaum, 2011).

According to Amigues (1988), in order to induce conceptual changes through collaboration, instructional interventions are usually conducted following the socio-cognitive conflict design. This design is based on the idea whereby the pairing of students with different initial conceptions will lead to a cognitive conflict. As a result, they will then seek for equilibrium to accommodate their naive concepts with scientific concepts. When students' existing concepts are activated and integrated with scientific explanations, this will lead to an imbalance (Kendeou and Broek, 2007), which will trigger deeper information processing that cause conceptual changes. Furthermore, Mason (1996) suggests that conceptual changes are likely to occur when students are asked to clarify, explain, and defend their own ideas. This is also consistent with Schwarz *et al*. (2000), whom suggested that the task of knowledge construction will be more effective if students are engaged in peer or group argumentation.

In order to successfully promote conceptual changes through group argumentation, the participants need to consider both sides of the argument, explain aspects of the problem that are anomalous to their existing conceptions, and confront with the discrepancies between their points of views (Nussbaum and Sinatra, 2003). These actions will allow students to engage in the process of deep thinking about the alternative concepts, and subsequently rebut their alternative frameworks, and change their conception. Furthermore, by considering the three levels of scientific representations, students will form a better understanding of the concepts (Beall *et al*., 1994; Bucat and Mocerino, 2009; Johnstone, 1991), which assists the process of conceptual changes. Bucat and Mocerino (2009) also suggested that the sub-microscopic level of representations should be knitted into the observable macroscopic and symbolic levels to enhance a student's understanding of chemistry concepts. Hence, this study examines conceptual changes in the context of scientific argumentation, especially in relation to the three levels of representations.

METHODOLOGY

This descriptive study involves fourth form science students in the district of Pasir Gudang, Johor, Malaysia. Two instruments, the Open-ended Scientific Argumentation Test 1 and 2 (OSAT 1 & 2) are first developed based on the fourth form chemistry syllabus. Both instruments consist of similar questions related to neutralization and the properties of acids and bases. Two similar instruments are provided in order to avoid repetitions which could affect the result of study. In the instruments, information about the phenomenon being studied and diagrams are provided to assist students in answering the questions. After seven lessons on acids and bases, students are first asked to answer the OSAT 1 in an allocated time. The arguments constructed in the OSAT 1 are assessed based on their accuracy and the three levels of representations in chemistry. If the presented argument consists of alternative framework in any of the argumentation element, that argument is classified as non-scientific. On the other hand, any argument with the correct concepts and without any alternative framework is classified as a scientific argument.

Thirty two (32) students who have constructed different and unique arguments are then selected through purposive sampling for the guided group argumentation process. In the group argumentation process, eight groups of four students, where each group consists of two students who have mastered the scientific concepts and two students with alternative frameworks, are formed (Webb, 1985). Each group is also guided by a researcher (McNeill *et al.,* 2006). According to Osborne *et al*. (2004), the characteristic of this combination is essential to create cognitive conflict among group members, which will trigger scientific argumentation.

After the formation of groups, students in each group are guided and encouraged to explain their constructed arguments, and to relate them to the three levels of representations. The argumentation processes are also recorded, transcribed and analysed using content analysis. Students are then asked to answer the OSAT 2, and their arguments are re-assessed to compare their mastery of scientific argumentation before and after the guided group argumentation processes.

RESULTS AND DISCUSSION

Mastery of Scientific Argumentation

The findings show that almost all of the students involved have changed their existing alternative frameworks to the correct scientific concepts after the guided group argumentation process. As shown in Figure 1, only 7.14% of arguments constructed by students contain alternative frameworks. Besides, content analysis shows that these students experienced alternative frameworks at the sub microscopic level but provided appropriate scientific concepts at the macroscopic level, as shown in Table 1. This indicates that scientific argumentation, especially in guided group setting promotes conceptual changes (Aydeniz *et al*., 2012; Nussbaum and Sinatra, 2003; Nussbaum, 2011).

Construction of Scientific Arguments at Macroscopic, Sub microscopic and Symbolic Levels

Table 1 shows that all students involved in the guided group argumentation can construct claim and evidence with correct scientific concepts. The element of reasoning is mostly constructed at the macroscopic and sub microscopic level (57.15%). While the constructed arguments consist of the element rebuttal, the percentage is lower than that of the other elements. These results suggest that guided group argumentation not only changed students' alternative frameworks to

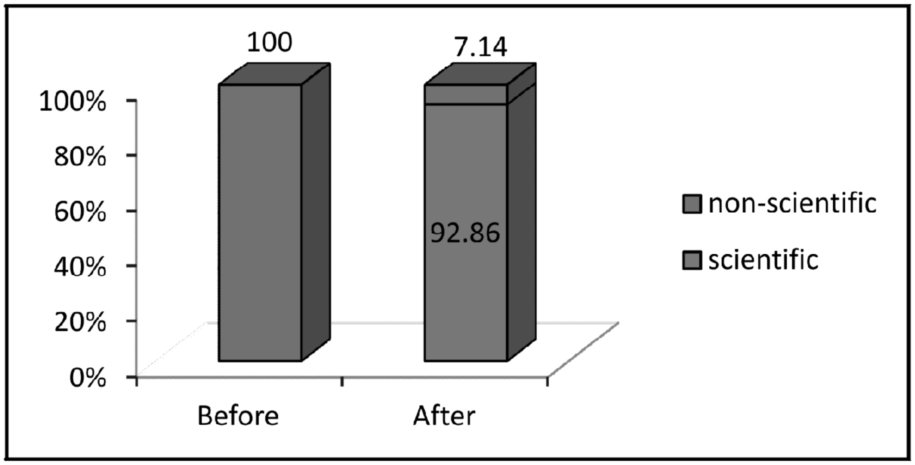

Figure 1: Comparison of students' mastery of scientific argumentation before and after guided group argumentation

TABLE 1: COMPARISON OF STUDENTS' MASTERY OF ARGUMENTATION ELEMENTS BEFORE AND AFTER GUIDED GROUP ARGUMENTATION

Element	*Before*			*After*		
	Scientific (%)	*Non Scientific (%)*	*No answer (%)*	*Scientific (%)*	*Non Scientific (%)*	*No answer (%)*
Claim	56.25	43.75	0.00	100.00	0.00	0.00
Evidence	50.00	50.00	0.00	100.00	0.00	0.00
Reasoning:						
Macro only	0.00	71.88	6.25	7.14	0.00	0.00
Sub micro only	0.00	0.00		3.57	0.00	
Macro and sub micro	12.5	9.37		57.15	7.14	
Macro, sub micro and symbol	0.00	0.00		25.00	0.00	
Rebuttal:						
Alternatif claim	12.50	3.12	84.38	60.71	0.00	39.29
Alternatif evidence	18.75	0.00	81.25	53.57	0.00	46.43
Alternatif reasoning:						
Macro only	3.12	18.75	78.13	14.29	0.00	28.57
Submicroonly	0.00	0.00		21.43	0.00	
Macro and sub micro	0.00	0.00		32.14	0.00	
Macro, sub micro and symbol	0.00	0.00		3.57	0.00	

the appropriate concepts, it also improved the quality of the arguments that are constructed (Aydeniz *et al.*, 2012; Nussbaum, 2011). These findings corroborate with Cross *et al.* (2008) who suggested that scientific argumentation can help students to reflect on their existing ideas and eventually eliminate the alternative frameworks that exist.

Analysis of argumentation processes transcripts show that the process of deep thinking involving sub microscopic level enables conceptual changes from alternative frameworks to scientific concepts. These findings support the study by Nussbaum and Sinatra (2003) which reported that scientific argumentative activities have potential in promoting conceptual changes among university students related to Newton's First Law.

Content analysis also shows that the scientific arguments constructed were accurate in terms of the scientific concepts and were complex in terms of the argumentation structure. Moreover, there are also arguments which showed the link between the three levels of representations. This suggests that students possessed deep and holistic scientific knowledge in the concepts being studied (Beall *et al*., 1994; Bucat and Mocerino, 2009). Table 1 also shows that more than half of the arguments constructed did include the element rebuttal. Thus, the arguments presented are considered complex and are of high quality since rebuttal is seen as a quality indicator (Erduran, 2007; Osborne *et al*., 2004; von Aufschnaiter *et al.*, 2008).

However, there are several students who constructed simple arguments that mostly consist of macroscopic level without the element rebuttal. Alternative frameworks also exist in the sub microscopic level. These results align with the findings by Dindar and Geban (2011), which reported that alternative frameworks are very difficult to eliminate. Thus, it is clear that scientific argumentation can promote conceptual changes, if students made an effort to construct evidence, reasoning and rebuttal at the macroscopic, sub-microscopic and symbolic levels.

Schematics of Conceptual Changes in Scientific Argumentation

Student's conceptual change scheme is identified based on the recorded argumentation processes and is shown in Figure 2. The schematic of conceptual changes shows the process of concept changed from alternative frameworks to scientific concepts when students are involved in a guided group argumentation.

Based on Figure 2, students who are involved in comparing and evaluating two alternative concepts at the macroscopic, sub-microscopic and symbolic levels would generally experience cognitive conflicts. Through the process of deep thinking, students are made aware of their alternative frameworks, which then allow them to replace it with the appropriate scientific concepts. This conceptual change enables students to completely understand the scientific concepts and subsequently enhances their mastery of any related concepts. Hence, scientific argumentation especially in group setting promotes conceptual changes (Aydeniz *et al*., 2012; von Aufschnaiters *et al*., 2008).

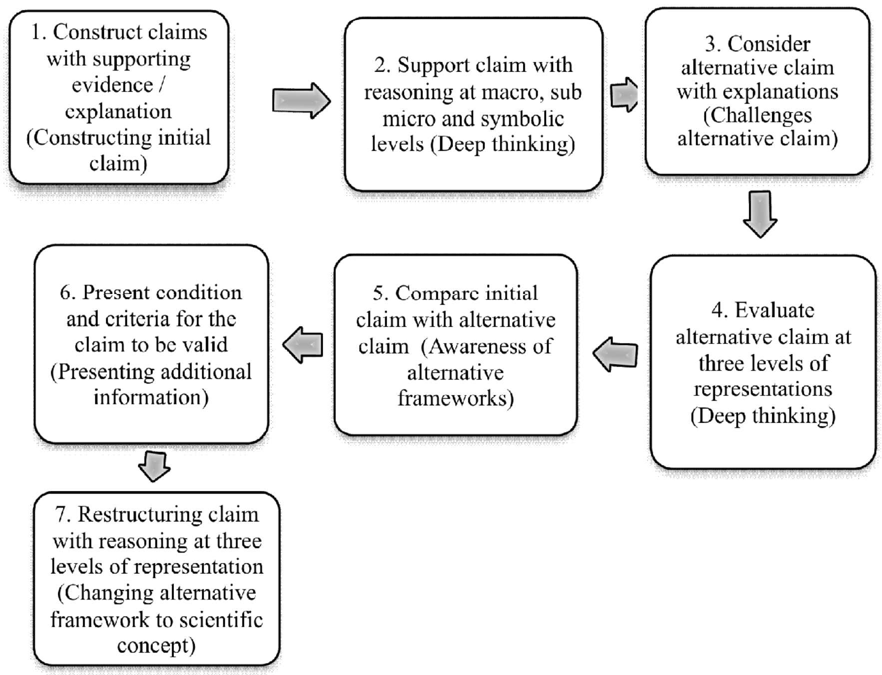

Figure 2: Schematics of conceptual changes in scientific argumentation

CONCLUSION

This study shows that conceptual changes occur when students construct scientific arguments that link between the macroscopic, sub-microscopic and symbolic levels of representations. While constructing arguments in a group setting, students tend to elaborate on their pre-existing ideas in a social context, thus providing opportunities to their peers to evaluate the rationality and accuracy of the ideas, as well as to provide feedback. The study also shows that the process of deep thinking about two alternative concepts at the three levels of representations helped with conceptual changes. It is observed that students tend to restructure and accommodate new concepts, if they are intelligible and plausible. Hence, the teaching and learning of science need to focus on group argumentation and incorporates the linkage between the macroscopic, sub-microscopic and symbolic representations to ensure students' understanding of scientific concepts.

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