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SCIENTIFIC ARGUMENTATION PRACTICE IN TEACHING SCIENCE

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Abstract: Scientific argumentation could enhance students' learning by promoting high-level thinking, producing students with science literacy, and eliminating misconceptions. Therefore, this research was conducted to study scientific argumentation practices in the science classroom, the roles of teachers and students during scientific argumentation, and the level of scientific arguments constructed in the classroom. Research was conducted using the mixed method. Teaching activities of four teachers were observed five times and then analyzed. In addition, respondents were interviewed. In decreasing order of frequency, the activities implemented by the teachers were explanation (43%), experimentation (29%), discussion (14%), exercises (13%), and others (1%). Scientific argumentation was only practiced during explanation and discussion, with the former being more frequent. Therefore, teachers acted mostly as argument constructors, and students acted as passive listeners rather than argument constructors with teacher facilitation. The levels of scientific arguments were only at Level 1, 2, and 3, with none reaching higher and more complex levels of 4, 5, and 6. Based on the findings of the research, an effort should be made to transform teaching activities to become more student-centered, which would offer opportunities for students to act as argument constructors, facilitated by teachers, to construct more complex arguments.

Keywords: Scientific argumentation, science teaching and learning, scientific argumentation elements, scientific argument levels.

INTRODUCTION

The aim in science education is to produce students with scientific literacy (National Research Council [NRC], 1996). To achieve this, teaching and learning must be effective. Teachers should be wise in planning their instruction to ensure effective science learning. Kementerian Pendidikan Malaysia (the Ministry of Education of Malaysia) has also suggested that inquiry teaching be implemented.

Unfortunately, science teaching in classes is still low. Past researchers (Hanri & Arshad, 2013; Heng & Surif, 2013; Ibrahim & Noordin, 2003) reported that science teaching and learning in Malaysia are polarized toward expository teaching where teachers explain concepts to passive students. The teachers play a more active role in explaining rather than discussing, while the latter could encourage scientific argumentation (Heng & Surif, 2013; Siew Li & Arshad, 2014a; Tay & Mohammad Yusof, 2008).

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Several researchers found teachers who claimed to practice inquiry teaching; however, these claims are not accurate since their practice was not in actuality inquiry teaching (Siew Li & Arshad, 2014a, 2014b; Yin, 2011). Many chemistry teachers in Malaysia are unaware of inquiry teaching (Yin, 2011), which suggests that inquiry teaching is not being done properly in classes since understanding the approach is important to ensure the inquiry method is being practiced effectively (Crawford, 2000).

Scientific argumentation is one of the methods that can be used to achieve the aim of science education. It is believed to play an important role in promoting students' learning process by encouraging high-level thinking (Eskin & Berkiroglu, 2008; Yalcinoglu, 2007); nurturing concept understanding; and eliminating misconceptions (Cetin, 2014; Nussbaum, 2011; Sadler, 2004), thus producing students with science literacy (Braaten & Windschitl, 2011; Cavagnetto, 2010) and increasing communication skills (Nussbaum, 2011; Marttunen, 1994).

Currently, the focus of scientific inquiry has shifted from assuming science involves only discovery and experimentation to scientific argumentation based on evidence and constructing excellent summaries (Duschl, Schweingruber, & Shouse, 2007; Driver, Newton, & Osborne, 2000), which are essential skills for future generations. Realizing the importance of scientific argumentation in science classes, science education globally has shifted to activities that encourage it in classes. The question is, has this been done in science classes in Malaysia?

SCIENTIFIC ARGUMENTATION PRACTICE

Argumentation can be divided into two types: monological and dialogical. The monological type is a one-way argumentation style that occurs within an individual and is then channeled out to the public to persuade others (Chin & Osborne, 2010; Jimenez-Aleixandre & Erduran, 2007; Newton, et. al., 1999; van Eemeren & Grootendorst, 2004). An example is teachers giving scientific explanations to students with no involvement from the students during the argumentation. This process offers no space for the students to be involved in the scientific argumentation process.

On the other hand, dialogical argumentation occurs interpersonally and involves discourse between individuals with different ideas (van Eemeren & Grootendorst, 2004) to find solutions for conflicts (Andriessen, 2006) by relating the evidence and claims made (Duschl, Schweingruber & Shouse, 2007). Argumentation requires students to react to claims by other students and themselves, to make explanations, to ask questions, and to rebut alternative ideas (Chin & Osborne, 2010). This kind of argumentation can occur through discussion. In dialogical argumentation, teachers facilitate students, and the students construct arguments.

Therefore, how do teachers practice scientific argumentation in class? Do they practice more dialogically or monologically? What are the roles of teachers and students during scientific argumentation?

SCIENTIFIC ARGUMENTATION ELEMENTS

Scientific argumentation is an activity that draws quality conclusions based on proof and justification and explains the relationship between a claim and proof (Driver et. al., 2000; Duschl et. al., 2007). Therefore, a statement must contain certain elements to be classified as an argument.

Most researchers have used Toulmin's argumentation pattern (TAP) to evaluate arguments by students (Bell & Linn, 2000; Dawson & Venville, 2009; Driver et. al., 2000; Erduran, Simon, & Osborne, 2004; McNeill & Pimentel, 2010). Moreover, TAP has six elements:

(i) claim, which is the conclusion or assertion
(ii) data, which is proof supporting the claim;
(iii) warrant, which is an explanation relating the proof and the claim;
(iv) backing, which is a presumption to strengthen the warrant;
(v) rebuttal, which is a condition if a claim is questionable or controversial and
(vi) qualifier, which are conditions for claims to be true.

TAP has also been simplified (Erduran et. al., 2004) to only five elements: claim, data, warrant, backing, and rebuttal.

In the present research, TAP were modified and used to analyze argumentation in the classroom. The warrant, qualifier, and backing are grouped based on their common value (Erduran et. al., 2004), which is justification, and one new element is added, refutation. A refutation is needed if a claim is questionable or controversial. Therefore, there are five elements in this study: claim, data, justification, refutation, and rebuttal.

Argumentation elements can be divided into two categories: basic and complex elements. Basic elements include claim, data, and justification, while complex elements include refutation and rebuttal. A sound argument should include complex elements.

Many researchers (Bell & Linn, 2000; Dawson & Venville, 2009; Driver et. al., 2000; Erduran et. al., 2004; Heng, Surif, & Seng, 2015; McNeill & Pimentel, 2010; Osborne et. al., 2004) have studied argumentation elements in students' written arguments only. However, argumentation elements need to be studied during teaching to determine the level of arguments commonly constructed in the classroom. Thus, the practice of scientific argumentation by teachers can be evaluated. Therefore, this research aims to study the level of scientific argumentation practiced in classes.

RESEARCH OBJECTIVE

The purpose of this research is to study scientific argumentation practice in teaching chemistry, which includes these objectives:

1. To study teaching activities that practice scientific argumentation;
2. To study teachers' roles during scientific argumentation practices; and
3. To study the levels of scientific argumentation practiced by teachers.

RESEARCH METHOD

A mix of quantitative and qualitative methods was selected for this study to measure the frequencies of the teaching activities and argumentation elements and the level of arguments. The research was conducted in an authentic environment without intervention during observation of the actual practice of scientific argumentation in class.

Four respondents, chemistry teachers around the district of Johor Bahru, were randomly chosen. These respondents used the same national curriculum provided by Kementerian Pendidikan Malaysia (Ministry of Education of Malaysia). Each respondent's teaching was observed five times and was recorded and transcribed for analysis. Follow-up interviews based on the analysis were conducted.

For the first objective, the analysis started with the identification of the teaching activities. The temporal durations of the activities were recorded and translated into percentages. In each activity, the arguments were identified, recorded, and coded (as PS), and the frequency was calculated.

For the second objective, the origins of the arguments were classified as either coming from the teachers and/or the students. The frequency and percentage of each class was then measured. The same procedure was applied in classifying the argumentation elements.

Finally, the elements in each argument were identified. These elements determined the level of argumentation, described in Table 1. The frequency and percentage values of each argument were also calculated.

TABLE 1: THE LEVELS OF SCIENTIFIC ARGUMENTATION

Level	*Description*
1	Argument contains only claims.
2	Argument contains claims and one argumentation element.
3	Argument contains only the basic argumentation elements.
4	Argument contains claims (with evidence or justifications) and one complex argumentation element (refutation and/or rebuttal).
5	Argument contains basic argumentation elements and one complex argumentation element.
6	Argument contains all basic and complex argumentation elements.

RESULTS AND DISCUSSION

This section is divided into three subsections based on the objectives of the study.

A. Teaching Activities that Promote Scientific Argumentation

In Table 2, the most frequent activity conducted by teachers is explanation, which was 43% of the total teaching duration. This result is in agreement with the findings of past researchers (Hanri & Arshad, 2013; Heng & Surif, 2013; Ibrahim & Noordin, 2003; Siew Li & Arshad, 2014a; Tay, 2010). This result also suggests that teaching and learning activities in classes were teacher-centered. Teachers actively explained scientific theories or facts to passive students.

TABLE 2: TEACHING ACTIVITIES OF CHEMISTRY TEACHERS

Teaching Activities	*GK1*	*GK2*	*GK3*	*GK4*	*Percentages*
Explanation by teachers	60%	39%	34%	40%	43%
Whole class discussion	22%	24%	1%	8%	14%
Experiments	4%	14%	54%	44%	29%
Exercises	12%	23%	10%	8%	13%
Others	2%	0%	0%	0%	1%

Additionally, 29% of the total teaching time was used to conduct experiments. This activity refers only to the time when the students were doing the experiments. Discussion regarding experiments is included in the discussion category. Only 14% of the total time in class was used for whole class discussion with the potential of involving students in constructing scientific arguments dialogically (Driver et. al., 2000; Heng & Surif, 2013). The other 14% of the class time was used for exercises and other activities, such as video presentation. The exercise activity may have included arguments but was not considered in this study since only arguments constructed in discourse were considered.

Table 3 shows the identified argumentation activities during teaching activities. Two types of argumentation detected were dialogical argumentation during explanation and dialogical argumentation during discussion.

TABLE 3: ARGUMENTATION ACTIVITIES IN CHEMISTRY CLASSES

Teachers	*Teaching Activities*		*Total Argumentation*
	Explanation	*Discussion*	
GK1	13	17	30
GK2	11	14	25
GK3	6	0	6
GK4	9	1	10
Total	39	32	71

Many arguments were constructed during teachers' explanations, which were 39 times, as in PS67, compared to discussion at 32 times, as in PS47. This condition demonstrates that there are efforts from teachers to practice scientific argumentation, yet they are poorly executed.

PS67

Student/ Teacher	*Transcript*	*Argumentation Element*
Teacher	So, what you can see is high intensity of pink coloration. So, inference that we can make is pink coloration shows the presence of hydroxide ion. Then, no blue spot means no iron 2 ion presence.	Data
Teacher	When iron 2 ion thus not present means that iron thus not rust (when protected with more electropositive metal).	Clam
Teacher	So, the explanation is magnesium is more electropositive than iron … magnesium is easier to release electron compared to iron. So, magnesium will release electron to form magnesium ion ... Then, electron flow through the surface of water ... Water molecule with oxygen will receive electron to form ion. Hydroxide ion … So, hydroxide ion that cause the pink color.	Justification

PS47

Student/ Teacher	*Transcript*	*Argumentation Element*
Teacher	How about chemical properties of elements in Group 17?	
Student	All elements in Group 17 have same chemical properties	Claim
Teacher	Why do you think is that?	
Student	Because all elements in Group 17 have the same number of valence electrons	Justification
Teacher	What else?	
Student	Each atom will receive one electron to achieve stable electron arrangement.	Justification
Teacher	For example, all elements in Group 17 react with water to produce two types of acids.	Data

Based on these two examples, PS47 demonstrated better argumentation than PS67 since it involved students during the construction of the scientific argumentation. Teachers should include students during scientific argumentation practice to polish and improve students' weak argumentation skills (Heng et. al., 2015). Apart from that, by involving students during the practice, students' higher order thinking skills can be improved (Eskin & Berkiroglu, 2008; Yalcinoglu, 2007).

B. The Roles of Teachers and Students During the Practice of Scientific Argumentation

Table 4 shows the percentages of argumentation constructed by teachers, students, and both teachers and students. Based on the percentages, most arguments were constructed by teachers (52%), which is more than half of the constructed arguments. In this case, the teachers constructed all the elements in argumentation.

TABLE 4: PERCENTAGES OF ARGUMENTS CONSTRUCTED BY TEACHERS ONLY, TEACHERS AND STUDENTS, AND STUDENTS ONLY

Argument Constructors	*Percentage*
Teachers only	52%
Students only	27%
Teachers and students	21%

About 21% of the arguments were constructed by both teachers and students whereby the argument construction process was mostly controlled by the teachers, who contributed one or two argumentation elements. There were also teachers who gave full opportunity to students to construct arguments and provided only some help in questioning; however, the percentage was still low (27%). Teachers should give more freedom and opportunity to students to increase their argumentation skills and higher order thinking skills.

Based on the percentages of the argumentation elements, teachers constructed most of the argumentation elements (64%), while the remaining 36% were contributed by the students, as shown in Table 5. These results show that more than half of the arguments were constructed by the teachers, which suggests that the teachers were dominant during argument construction and students were passive. This agrees with findings where students were only listeners and passive learners in class (Heng & Surif, 2013; Siew Li & Arshad, 2013; Tay & Arshad, 2008).

TABLE 5: PERCENTAGES OF ARGUMENT ELEMENT CONSTRUCTORS

Element Constructors	*Percentage of elements*
Teachers	64%
Students	36%

C. Level of Scientific Argumentation in Classes

The levels of detected arguments were based on Table 1. Figure 1 shows the frequency of arguments for each level of scientific argumentation. The results show that the highest level of argument constructed is only at Level 3 with most (54%) at Level 2. These results correspond to findings reported by Karpudewan, Roth, and Sinniah (2016), who found that teachers who taught in an authentic environment without any intervention only constructed arguments at Levels 2 and 3. The following is an example of arguments constructed in a class during a discussion for Level 1 (PS3).

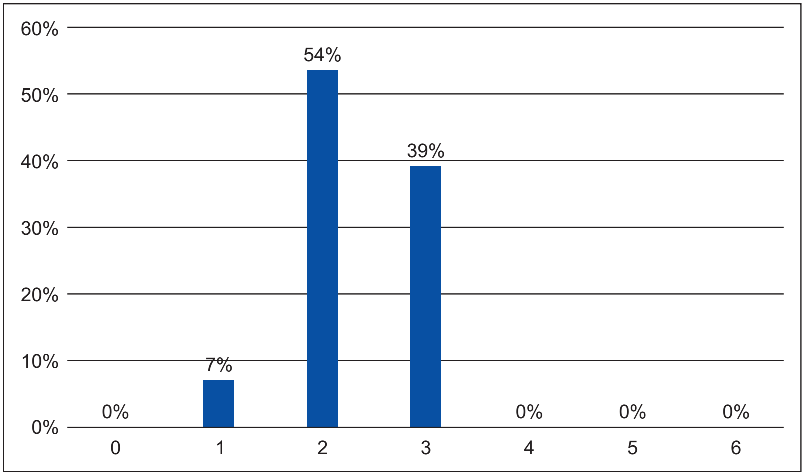

Figure 1: Percentage of argument for each level

PS3

Student/ Teacher	*Transcript*	*Argumentation Element*
Teacher	Can Group 17 elements conduct electricity?	
Student	No.	Claim
Teacher	They can't conduct electricity.	

Based on example PS3, teachers asked students about the general properties of Group 17 elements. The answers given were correct, but the teachers discontinued the discussion by asking for different argumentation elements from the students. The teachers could have asked the students why it did not conduct electricity (justification) and to predict whether an electrical conductivity experiment existed (data).

Teachers could challenge the students' ideas by asking for the reasons an element could conduct electricity (rebuttal) and what should result from an electrical conductivity experiment (refutation). This condition also happens during discussion to construct Level 2 arguments (PS46).

In the example of PS46, teachers asked many questions; however, the questions were limited to justification. The teachers discontinued the problem by not extending the questions to another line of argumentation, such as asking for data or challenging the ideas by asking what would happen in a different scenario.

PS46

Student/ Teacher	*Transcript*	*Argumentation Element*
Teacher	What are the trends of melting and boiling points of Group 1 elements as they go down the group?	Claim
Student	Decreasing.	
Teacher	Why does it decrease? There are three points. The first point is?	Justification
Student	Atomic size increase.	
Teacher	Atomic size increase. What's next?	
Student	Metallic bonding is weaker.	
Teacher	Ok, …. The last point is?	
Student	Lesser heat energy needed to overcome attraction forces between atoms.	

However, there were few efforts shown by the teachers to construct more complete Level 3 arguments. At this level, discussions become more complex with further questions asked by the teachers, as in the example of PS18.

In the example of PS18, teachers frequently asked questions. Teachers also asked more of the argumentation elements compared to Level 1 and 2. However, arguments were still lacking in the two complex argumentation elements (refutation and rebuttal). Teachers did not challenge the students' ideas. Teachers only focused on the correct answers and did not anticipate problems holistically. Teachers could have challenged the students' ideas by asking what would happen to the elements' ignition as their reactivity decreased (rebuttal) and to make a prediction of atom sizes if their reactivity decreased (refutation).

PS18

Student/ Teacher	*Transcript*	*Argumentation Element*
Teacher	Ok. Let's see the observation on page 58. Lithium first. Lithium moves slowly with red flame on water surface … what is the inference?	Data
Student	Less reactive.	
Teacher	Less reactive based on the slow movement … lithium is less reactive … sodium moves fast with yellow flame. What is the inference for sodium?	
Student	Reactive.	
Teacher	Reactive. Potassium is most reactive because it moves faster on water surface.	
Teacher	As a conclusion, from lithium to potassium the reactivity increases or decreases?	Claim
Student	Increases.	

Student/ Teacher	*Transcript*	*Argumentation Element*
Teacher	Why does it increase?	Justification
Student	Atomic size increases when going down the group.	
Teacher	Ok, great.	
Student	Distance increases.	
Teacher	Which distance are you referring to? Distance between nucleus and electron increases. What else?	
Student	Attraction force between nucleus and electrons decrease.	
Teacher	The last point?	
Student	Easier to release.	
Teacher	Easier to release electrons.	

The absence of high-level arguments is caused by teachers not stressing complex argument elements (refutation and rebuttal) during the argumentation process, as shown in Table 6. Teachers only focused on the claim element (71), data element (30 counts), and justification element (64), while no instances were recorded for refutation and rebuttal elements.

TABLE 4: TABLE STYLES

Argumentation Elements	*Frequency*
Claims	71
Proof	30
Justification	64
Refutation	0
Rebuttal	0

This condition escalated from the fact that the teachers did not challenge the students' ideas and only focused on the correct answers, as reported by Hanri and Arshad (2013). If there is no challenge from a teachers or other students, or if contradictory ideas are not highlighted by the teachers, no counter claims can cause refutation and rebuttal elements to be included in the argumentation.

Teachers' limited knowledge also contributed to this problem. Based on the interviews, teachers were not aware of scientific argumentation and its elements. However, the teachers did practice argumentation, but limited knowledge caused them to neglect certain elements in argumentation.

Additionally, the low data element count showed that most arguments were not included with proof to strengthen the arguments. This would make it difficult for students to include data to support the presented arguments as reported (Chen et. al., 2011; Kuhn, 1989; Kuhn et. al., 2000; Zeidler, 1997). Teachers should also stress the data element to support arguments and not only by acquiring/giving justification elements.

CONCLUSION AND IMPLICATION OF THE STUDY

It was found that teachers who were mostly teacher-centered implemented teaching practices that were unconducive to argumentation practice, as reported by Rivard (2004), Kamaruddin (2001), and Newton et. al., (1999). Teachers used numerous explanation activities compared to other activities more conducive to practicing scientific argumentation, such as discussion. Therefore, teachers should conduct more student-centered activities to avoid monological argumentation activity.

From the aspects of scientific argumentation practice, teachers are more likely to construct arguments rather than provide the opportunity for the students to do so. However, there are limited numbers of teachers who do this. Teachers need to provide opportunities for students to construct scientific arguments and should not only facilitate them.

Arguments were only at low levels of 1, 2, and 3. The absence of higher levels of arguments was due to the absence of complex argumentation elements. To create these complex argumentation elements in class, teachers or the students themselves must challenge their ideas, or the teachers must be more open and not only focused on correct answers.

In conclusion, an effort should be made to increase scientific argumentation practice and science education in Malaysia. Teachers should be exposed to the authentic concept of scientific argumentation so that the scientific argumentation process can be executed effectively. Extensive research to develop a module to assist teachers in practicing scientific argumentation should be conducted. Moreover, research on the problems hindering scientific argumentation practice among teachers also should be done to deeply understand the reasons that teachers are not sufficiently practicing it.

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