Scientific Argumentation Practice and Verbal Interaction in Chemistry Classroom Among 10th Grade Students

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Abstract*: Practicing scientific argumentation is believed capable of nurturing higher order thinking and scientific literacy among students. Yet, it has not been well practiced as evidenced by typical classroom teaching activity. The purpose of this research is, to study the practice of scientific argumentation among chemistry teachers through the argument level and classroom verbal interaction pattern. Four chemistry teachers and their students from Johor Bahru, a district of Johor was selected as the participants of this qualitative research. Five observations for each teacher had been conducted and observation become the principal method of data collection. Findings shows that the scientific argumentation being constructed in class was only at Level 1 (7%), Level 2 (54%) and Level 3 (39%). No higher and complex argumentations were found. Two interaction patterns, Initiation-Response-Evaluation/Feedback (IRE/IRF) (18%) and Initiation-Response-Feedback-Response-Feedback (IRFRF) (82%) were detected when teacher were practicing scientific argumentation. The interaction pattern practices, IRFRF is good, yet the argumentation being constructed is still at low level as higher argumentation seems to be beyond the samples' ability. A further research probing into how IRFRF interaction pattern can be further enhanced to nurture complex argumentation is needed.

***Index Terms*: Scientific argumentation; Scientific argument level; Verbal interaction**

I. INTRODUCTION

Classroom scientific inquiry practice paradigm has shifted from science as experimental and exploratory activity toward explanation and argumentation construction activity [1,2], better known as scientific argumentation. It has been emphasized significantly in the National Science Education Standards documents in the United States [3, 4] and as the centre of debate among major figures in science education research [5 – 7]. Learning science is no longer memorizing facts without understanding its underlying concepts, it is now engaging students in argumentation process involving insight into what is data, bridging question with its claim to construct scientific argument [8] as being emphasized by science education.

Scientific argumentation is believed capable of enhancing students learning primarily in fostering higher order thinking [9-10], reasoning skill, catalysing conceptual understanding and preventing misconception [11-13], producing students that embrace science literacy [1, 14] as well as improving communication skill [12, 15].

A. The Practice of Scientific Argumentation in Science Classroom

The key objective of science education is ensuring students are scientifically literacy [4]. To achieve this, teaching and learning process must be effective and impactful. It demands teacher to be prudent in managing teaching process to ensure an impactful science learning is realizable. This leads to the Malaysia Ministry of Education manoeuvre of introducing inquiry into the science classroom.

In classroom, science teaching is ineffective. Literature [16-18] reported that science teaching and learning in Malaysia has been concentrating on expository-based teaching with teacher act as the centre of knowledge and students complimenting as passive listeners. Teacher retain much of the classroom control through explanation activity which minimizing discussion that might encourage scientific argumentation [17, 19-21].

Some teachers have been practicing inquiry in their teaching, yet it was not done effectively with notable deviation from inquiry teaching theory [20, 22, 23]. In Malaysia, trained chemistry teachers without in depth knowledge on inquiry teaching still exist [23]. This situation shows that, effective inquiry teaching is not achievable as understanding an approach is imperative in ensuring its effectiveness [24].

Students' written argumentation is still at low level as reported by [25], as in natural classroom, argumentation consists of claim supported by only one justification and/or data. Research done by [26] also reported students construct simple argument without any element of complex argumentation and show misconceptions at various chemistry levels. This might be due to low scientific argument construction in the class. Therefore, this research is to determine levels of scientific argument being constructed in science classrooms.

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B. Scientific Argumentation Element

Scientific argumentation is defined as argument construction activity, namely constructing high quality conclusion based on data and the relationship between claim and data being explained through warrant [2, 5]. Thus, a statement should comprise of several elements for it to be classified as argument.

Literatures are using Toulmin's Argumentation Pattern (TAP) in assessing arguments constructed by students [5, 27-32]. TAP consists of six elements: (i) claim which is conclusion or statement; (ii) data as prove to support the claim; (iii) warrant serve as the bridge between the claim and the data; (iv) backing as assumption that reinforce the warrant; (v) rebuttal in case claim is wrong; (vi) qualifier serving as conditions for an argument to be accurate. TAP has been simplified by Erduran, Simon & Osborne [29] into only five elements, namely claim, data, warrant, backing and rebuttal. In this research, the stated elements are modified and used to detect any argumentation in classroom. Warrant and backing being combined as they are almost the same [29] and another element, refutation is added. Refutation is the best data if argument is wrong. Hence, this research probe into five elements namely, claim, data, warrant, rebuttal and refutation.

Argumentation elements are also divided into two categories, namely the basic element and the complex one. The basic consists of claim, data and warrant while the complex comprises of rebuttal and refutation. A good argument needs to be complemented by the complex one.

However, based on literature, only students written argumentation were being studied [25-32]. Indeed, argumentation element is imperative in teaching process and need to be studied to determine the argument level being fabricated in classroom. Teachers' scientific argumentation can be examined either it being well practiced or not via argument level determination. Therefore, this study aims to probe into what is scientific argumentation level practices in classrooms.

C. Verbal Interaction during Scientific Argumentation

Argumentation is categorised into monological and dialogical. Monological is defined as one way argumentation that takes place in individual and voiced out to the public with intention of persuading others to consent the argument [6, 33-35]. Teacher making clarification to student on scientific theory is an example of this argumentation. However, students are not part of the argument construction process. For dialogical argumentation, it must occur between two or more individuals. It involves serious discourse as individuals debating with each other and embrace their own unique idea [34] and its objective is to find solutions to a conflict [36] through erecting link between data and claim made [2]. Argumentation requires students to respond toward others' claims using their own argument and counter-argument, constructing explanation, asking question and denying alternative idea [33]. Such argumentation can take place in classroom through in classroom discussion activity. In dialogical argumentation process, teacher act as facilitator and student must act as argument constructer. Therefore, this research also aims to analyse dialogical argumentation in science classroom.

Teacher - student interaction is crucial in encouraging dialogical argumentation. Lemke [37] stated three common interaction movement in science classroom are (i) initiation (I) that routinely start with closed-ended question by teacher, (ii) student's response (R) and, (iii) teacher's evaluation which involve praise for correct response and fixing wrong response from students (E); this is known as IRE. This interaction movement is also recognised as IRF – initiation, response and follow-up/feedback [38]. The deviation between IRE and IRF is, the third movement is not necessarily initiated from teacher. It can be teacher response anticipated to investigate further into student's idea, encouraging hypothesis construction and challenging student's idea [39].

Triadic dialogue has been commonly practiced in the traditional teaching. It grants content learning regulation to teacher and increasing students' attention through close and specific questioning [40]. It also facilitates teacher in teaching scientific facts to students [41]. Yet, it discourages higher order thinking among students as questions are at the low level in nature that demand just a brief response from students [42]. It renders this movement as inappropriate to be practiced in scientific argumentation as it results in brief argument.

Mortimer & Scoot [43] had joined IRE/IRF into Initiation-Response-Feedback-Response-Feedback (IRFRF) with idea challenging teacher's response lead to open and wide responses from students. Such movement inspires students' thinking and complex interaction. Research by Santos [44] find out that IRFRF is a chain of interaction noticeable during inquiry teaching. It is more open in nature that induce further discussion in class. As mean of encouraging complex argument, teacher should prudent in responding to student, safeguard it not finished at IRE/IRF but endure to IRFRF chain construction.

This research is conducted to determine what is the interaction sequence during multiple argument level construction and what is the interaction sequence to produce a complex argument.

II. RESEARCH OBJECTIVE

The purpose of this research is to study teacher scientific argumentation practice in chemistry classroom based on verbal interaction. The research objectives are:

(i) To determine the level of scientific argumentation constructed in classroom
(ii) To analyse teacher interaction pattern during scientific argument construction

III. METHODOLOGY

To achieve the objective of this research, a descriptive study was conducted qualitatively to assemble depth and holistic information on scientific argumentation practice. The research was conducted in a natural setting without any intervention as mean of probing into the actual scientific argumentation practice in classroom.

Scientific argumentation practice were evaluated by determining scientific argument being constructed in class and the level of scientific argument that being constructed. The main instrument used for this research is classroom observation.

Four chemistry teachers that taught Grade 10 students from Johor Bahru, a district of Johor were selected as participants of this research using purposeful random sampling method. Their permissions were obtained before classroom observation being conducted. All teachers used the native language, Bahasa Malaysia when teaching. Teaching and learning had been conducted in classes for theory learning and in laboratory for experiment session.

Each teacher was observed for five times, two theory sessions and three experiment sessions. Teachers' teaching was recorded using video recorder with their permission. The video then transcribed before being analysed thematically. Then, it was validated by expert to make sure the analysis was valid and reliable.

In analysing the data for the first objective, argument is spotted when there is claim to be argued. Any spotted argument is coded as SA. Later, the level of argument is determined using adaptation from research by [29] as in Table 1 and who constructed the argument will be decided.

Table 1: Scientific Argumentation Level

Level	Description
1	Argument that only consist of claim
2	Argument that consist of claim complimented by another argumentation element
3	Argument that consist of basic argument element
4	Argument that consist of claim, followed by data or warrant with a complex argument element namely rebuttal or refutation or both.
5	Argument that consist of basic element and complimented with another complex element
6	Argument that comprise of all basic and complex element

Finally, only argument constructed through discussion will be taken into the third objective analysis. This is since, if an argument is constructed by teacher themselves during explanation, then no interaction pattern is taking place. The interaction pattern of the constructed argument is decided based on research on interaction pattern by [42,43].

IV. RESULT AND DISCUSSION

This section is separated into two sub-sections based on the research objective.

A. Scientific argument level during teacher teaching

To understand the role of teacher and student in higher level argument construction, the scientific argumentation level wa identified. The recorded argument is used to decide the scientific argumentation level. Scientific argumentation level is determined as in Table 1. In Figure 1, the argument frequency for each scientific argumentation level is illustrated.

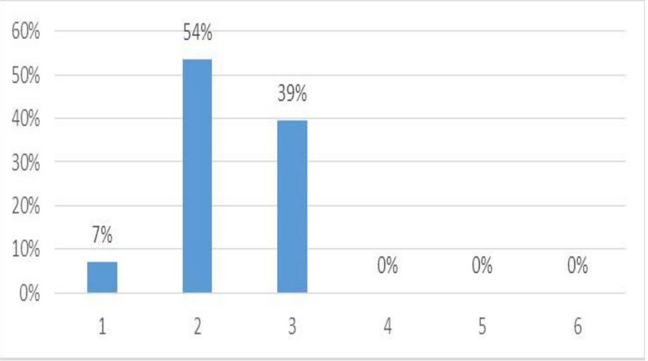

Figure 1: Frequency of argument for each level

Based on the finding, the highest argument level constructed is only at Level 3. The majority of the argument is only at Level 2 which is equivalent to 54%. This lead to student inability to construct complex argument with higher level. This has been proved by [25] who found that students were only able to construct a brief argument at Level 2 and Level 3 if the teacher is teaching in typical condition, while students who had been exposed toward complex scientific argument in classroom able to construct a complex argument.

The absent of higher argument level is due to the teacher not emphasizing complex argument element, such as rebuttal and refutation in argument construction process as demonstrated in Table 2. This condition is triggered by teacher preference not to challenge other student idea, instead focusing toward the correct idea as reported by [16]. Short of contest from teacher or other student or if conflicting idea is not being given attention by teacher, thus no counter-argument that generate rebuttal and refutation elements in argument construction.

Table 2: Spotted argumentation element frequency

Argumentation Element	Frequency
Claim	71
Data	30
Warrant	64
Rebuttal	0
Refutation	0

B. Interaction pattern during scientific argumentation

To understand the interaction pattern during scientific argumentation, only arguments constructed by student and teacher with student are analysed. As monological argumentation does not involve any interaction, arguments constructed by teacher are set aside. There are two interaction pattern documented while teacher is practicing scientific argument which are IRE/IRF (18%) and IRFRF (82%) as shown in Table 3. IRFRF has shown higher frequency when teacher constructing arguments. It indicates IRFRF is vastly suitable to be used during scientific argumentation practice as it is open in nature and can further expand students' idea [42, 44].

Table 3: Interaction pattern for each argumentation pattern

Teaching sequence	Argumentation Pattern	Frequency	Total percentage
IRE/IRF	Level 6	0%	18%
	Level 5	0%	
	Level 4	0%	
	Level 3	3%	
	Level 2	9%	
	Level 1	6%	
IRFRF	Level 6	0%	82%
	Level 5	0%	
	Level 4	0%	
	Level 3	33%	
	Level 2	49%	
	Level 1	0%	

IRFRF pattern has been proven itself as better than IRE/IRF as no Level 1 argumentation level was detected for IRFRF pattern and IRFRF interaction pattern generates more arguments at Level 2 and Level 3 if compared to IRE/IRF. Yet, the IRFRF pattern practices by teacher is not ideal as no argument at higher Level 4, Level 5 and Level 6 were spotted in teacher teaching.

Several teachers practice IRE/IRF pattern in argument construction. This pattern is not superlative as it generates brief and weak argument as example by Table 4, SA3.

Table 4: Scientific Argumentation Transcript 3

	S / T	Transcript	Int	AE
1	T	So it (Group 18) exists as dimono?	I	
2	S	Monoatom	R	C
3	T	As it is stable, it exists as monoatom	F	W
Notes S – Student; T – Teacher; I – Initiation; R – Response; F – Feedback; Int – Interaction; AE – Argument Element; C – Claim; W - Warrant				

SA3

Teacher questioning is only at the beginning of the argumentation (line 1). After student proposing claim as response to teacher's question, teacher provide warrant without asking for student's justification. Teacher may ask student to suggest an evidence through question "how many valence electrons in Group 18 element?" before asking for justification through question such as "why does it exist as monoatom?" and "why when it is stable, it able to be monoatom?". Questions such as these may facilitate student in constructing a much more complete and robust argument especially, to justification and not only teacher offering justification.

The application of IRFRF pattern lead to brief argument, however, it is better that IRE/IRF if teacher is weak in using multiple questioning technique as shown in Table 5, SA 13. In SA13, warrants are constructed stronger and much robust compared to SA3. As teacher has applied IRFRF constantly to generate more justification from student. It happens in line 3 to 8, with teacher keep asking questions to facilitate student in generating stronger and complete when student give incomplete justification as response to teacher's question.

Table 5: Scientific Argumentation Pattern 13

	S / T	Transcript	Int	AE
1	T	Does Group 18 exhibit any chemical characteristics?	I	
2	S	No	R	C
3	T	No, chemically unreactive. Chemical characteristic of Group 18..... Why does it not reactive?	F	
4	S	It has achieved octet stability	R	W
5	T	Its electrons configuration has achieved octet stability or duplex, so?	F	
6	S	It does not reactive to donate or receive electron	R	W
7	T	Or?	F	
8	S	Sharing electron	R	W
9	T	Or sharing electron with another element	F	
Notes S – Student; T – Teacher; I – Initiation; R – Response; F – Feedback; Int – Interaction; AE – Argument Element; C – Claim; W - Warrant				

SA13

The following is example of Level 3 argument argumentation as teacher practices IRFRF repeatedly as in Table 6, SA 21. Argumentation session begins with teacher giving clarification on experiment observation conducted. Next, teacher trigger a discussion that constructs argument through a question that asking for conclusion on the conducted experiment (line 2). Teacher asking question about the experiment conclusion to acquire claim from student which is the increasing reactivity for Group 1 element when descending the group. Student's response (line 3) was followed by question from teacher asking for justification why the reactivity is increasing when descending the group (line 4). Even though student is giving justification at line 5, but it is incomplete. Therefore, subsequent question was given by teacher (line 6) by ordering other student to further giving explanation and completing the justification. The condition continues until complete justification was given by student at line 12.

Based on example SA 21, the application of series of questions and not stopping at IRE/IRF only is proved as impacting students' argumentation. IRFRF pattern leads to much completed argument. Yet, the argument is still lack of rebuttal and refutation elements. Teacher should continue giving triggering responses to gain rebuttal and refutation from student in challenging student' idea arrangement.

Table 6: Scientific Argumentation Transcript 21

	S/T	Transcript	Int	AE
1	T	Ok, the reaction with oxygen is the same with chlorine gas. We look at lithium first…. Ok, its flaming for lithium is red. The same concept for sodium with yellow and potassium as purple. Lithium will burn with red flame. Then, put it into the gas chamber filled with oxygen and white fume will be produced. The white fume is lithium oxide. And put it in water… the product will be lithium hydroxide. So, lithium, lithium burns with red flame. White solid produced, colourless solution turns the green universal indicator to purple. Sodium burns with bright yellow flame, producing white solid, colourless solution turns the green universal to purple. The same as before this. Ok potassium. Burn with very bright purple flame, producing white solid, dilute in water forming a colourless solution. Changing green universal indicator to purple… So, how the equation can be made? First, react with oxygen, then react with water. Fast Divana (teacher order student to write the equation on white board).	I	D
2	T	Done. Sodium oxide just dissolves in that water. It reaction just dissolves. Dissolve in water producing potassium hydroxide…. In conclusion, from lithium to potassium, its reactivity is increasing or decreasing?	I	
3	S	Increasing	R	C
4	T	Why it is increasing? Why increasing?	F	
5	S	Atomic size increasing	R	W
6	T	Ok, good. Sit first, not yet the time to go back now. Ok Yanti.	F	
7	S	The distance between the nucleus and electrons is increasing.	R	W
8	T	Distance between? The distance between the nucleus and electrons is increasing. Come on, the third point. Sit first Arina, Asri.	F	
9	S	The pulling force between the nucleus and the electron is weakening.	R	W
10	T	The pulling force between the valence electron with the positively charged nucleus at the center is weakening. Far distance, weaker force. So the last point.	F	W
11	S	Easy to be released	R	W
12	T	Electron can be easily released	F	W

Notes
S – Student; T – Teacher; I – Initiation; R – Response; F – Feedback; Int – Interaction; AE – Argument Element; C – Claim; W – Warrant, D - Data

SA21

V. CONCLUSION

This research finds that arguments being constructed in classroom are still at lower Level 1, Level 2 and Level 3. No higher argument is due to the absence of complex argumentation element. To generate complex argumentation element in classroom, teacher needs to challenge student's idea or granting opportunity for other student to challenge that idea as well as acting flexibly and not focusing only toward the correct answer.

IRFRF pattern is proven as capable of generating higher quality argument when compared to only IRE/IRF. Through IRFRF interaction, teacher could catalyse student's idea, asking for other argumentation element or asking for further clarification from student through feedback given by the student. The flexible IRFRF pattern creates chances for teacher to facilitate the student in creating higher quality and complex argument compared to IRE/IRF that tend to be more close and restricted.

Although teacher conduct lots of IRFRF interaction, the argument constructed is still at low level. It was prompted by poor teacher's feedback toward student's response. Teacher tend toward giving clarification or reinforcement without challenging student's idea. A further research is needed to study how good feedback from teacher catalysing complex argument construction.

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