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Teacher's Questions in Laboratory and Theory Chemistry Lessons

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Abstract

Inquiry teaching is one of the teaching approaches suggested in chemistry curriculum. This mixed-method study was used to investigate teacher's questions in chemistry's laboratory and theory lessons. This study also determines pattern of teaching sequence(s) during chemistry lessons. Twenty three chemistry teachers who applied inquiry teaching were involved in this study. Data were collected using an observation instrument named Observation Instrument in Inquiry Teaching through Verbal Interaction and semi-structure interviews. Data were analysed using descriptive statistics. Recorded classroom observations were transcribed verbatim and analysed manually. Findings revealed that most of teacher's questions were related to content in theory lessons. Meanwhile, in laboratory lessons, chemistry teachers emphasised almost equally both aspects; content and science process skills as required in inquiry teaching practices. In terms of pattern of teaching sequence, although IRE (initiation, response followed by evaluation) was still dominant in chemistry lessons observed, however, IR (Initiation followed by response), which supports inquiry teaching was found in this chemistry curriculum. This study showed that inquiry teaching in chemistry lessons need to be strengthened by planning it in chemistry lessons systematically in order to inculcate curiosity among the students.

Keywords: Inquiry teaching; teacher's question; science process skills; pattern of teaching sequence; verbal interaction

Abstrak

Pengajaran inkuiri ialah salah satu pendekatan pengajaran yang disarankan dalam kurikulum kimia. Kajian yang menggabungkan pendekatan kuantitatif dan kualitatif ini bertujuan untuk mengkaji soalan guru kimia dalam kelas amali dan teori. Dua puluh tiga guru kimia yang mengajar kimia berdasarkan pendekatan inkuiri terlibat dalam kajian ini. Pengumpulan data dilaksanakan dengan menggunakan instrumen pemerhatian iaitu Instrumen Pemerhatian dalam Pengajaran Inkuiri melalui Interaksi Verbal (IPPIVI) dan temu bual semi-struktur. Data dianalisis dengan menggunakan statistik deskriptif. Rakaman pemerhatian bilik darjah ditranskrip verbatim dan dianalisis secara manual. Dapatan kajian menunjukkan kebanyakan soalan guru di dalam kelas teori lebih banyak menekankan aspek kandungan. Sementara itu, bagi kelas amali, guru memberikan penekanan kepada kedua-dua aspek, iaitu aspek kandungan dan kemahiran proses sains sepertimana ditekankan dalam pengajaran inkuiri. Dari aspek corak urutan pengajaran, walaupun IRE (permulaan, maklum balas, disusuli dengan penilaian) masih dominan dalam kelas kimia; IR (permulaan diikuti dengan maklum balas) yang menyokong pengajaran inkuiri turut ditemui dalam kajian ini. Kajian ini memperlihatkan bahawa pengajaran inkuiri dalam mata pelajaran kimia masih perlu ditingkatkan dan dilaksanakan secara sistematik bagi melahirkan pelajar yang bersifat ingin tahu.

Kata kunci: Pengajaran inkuiri; soalan guru; kemahiran proses sains; corak urutan pengajaran guru; interaksi verbal

1.0 INTRODUCTION

Inquiry teaching has been emphasized in Malaysia as one of suggested teaching and learning approaches in teaching science subjects (Curriculum Development Centre, 2000; 2001; 2005). Chemistry secondary school teachers should apply inquiry teaching in the process of teaching and learning chemistry. National Research Council (2000) also recommended inquiry teaching as this approach enables students to grasp the chemistry concept through investigation. It was mentioned that inquiry is a process to find information, to question and to investigate phenomena surrounding them (*Curriculum Development Centre* ,2000, 2001; Crawford, 2000; Martin-Hansen, 2002; Hassard, 2005 and Douglas, 2007).

This pedagogical approach has proven to be effective and successful in enhancing students' thinking skills, critical skills, science process skills and the most important thing is student learn by *doing* science. Concurrently, this teaching approach involves students to discuss and carry out investigation or execute experiments to investigate a certain phenomena. Inquiry teaching is very important as it emphasize the process of teaching and learning of nature of chemistry (Abrams, Southerland and Silva, 2008). Besides than emphasizing on the content and nature of chemistry, application of science process skills are also important in inquiry teaching (Ciancilo, Bory and Atwell, 2006; Hammerman, 2006; Martin, Sexton and Franklin, 2009). So, the study scrunitized how chemistry teachers' questions were associated with content and science process skills.

Questions make up a big proportion of verbal interaction in science classroom as stated by Liston (2013). Furthermore, Dkeidek, Mamlok-Naaman and Hofstein (2011) stated that ability of questioning is vital in scientific inquiry. So, how chemistry teachers' questions in aspects of content and science process skills in chemistry lessons?

There are many previous researches on teaching sequence. Examples of researches are by Sinclair and Coulthard, 1975; Mortimer and Scott, 2003. Typical classroom scenario showed that common possible sequence after teacher's question is Initiation, Response and Evaluation or in simplified form as IRE. This was found in most classrooms in United States and also known as triadic dialogue (Lemke, 1990; Kumpulainen and Wray, 2002). In this sequence, teacher asks question(s), student(s) respond to the question, followed by teachers' evaluation (Sinclair and Coulthard, 1975; Mehan, 1979; Scott, Mortimer and Aguair, 2006). Same scenario was found here in Malaysia. Ng and Siow (2003) had carried out a research in one of the smart school. They found that a teacher starts with asking questions to students regarding the results of an experiment in the previous class, followed by explanation of the concept related to the experiment. Then students are asked to answer questions in the workbook individually and another student is asked to repeat the answer. On the other hand, inquiry teaching promotes discussion and further probing activities should display different teaching sequence(s). Teachers practicing inquiry teaching do not evaluate students' responses, which means they act neutrally (Lemke, 1990; Mortimer and Scott, 2003). This means the decision on the response given were made by students. This suggests that there should be other possible teaching sequence(s) in inquiry-based chemistry classrooms.

There are many studies that have proven that inquiry teaching can increase the students' understanding in science (Chang and Mao, 1999; Hakkarainen, 2003). Although there are many studies reported that inquiry teaching has a positive effect on students and relatively on students' science performance, nevertheless, there is only a handful of teachers who apply inquiry teaching in the teaching and learning process in the classroom (Keys and Bryan, 2001). The scenario is not only true locally but also quite prevalent in many other countries (Deters, 2004; Sampson, 2004; Windschitl, 2004; Singer, Hilton and Schwiengruber, 2005). They reported that inquiry was not being implemented in many classrooms. Furthermore, in the research carried out by Keys and Bryan (2001); Curriculum Development Centre (2001), found that teacher's inquiry teaching is different with the one intended by the curriculum developers. Research done by Po (2011) revealed that inquiry teaching was not implemented effectively. Hence, in order to investigate effectiveness of implementation of inquiry approach, this study looks into the nature of teacher's questions and pattern of teaching sequence.

In order to investigate the process of teaching and learning chemistry in classroom, verbal interaction can be used to analyse teacher talk. This is due to the fact that inquiry teaching involves a high interaction between teacher and student or between student and other student(s) (Suchman, 1966). Verbal interaction is anything that is being uttered. Verbal interaction in classroom comprises of teacher's question, teacher's statement, student's question, student's statement and silence or confusion. As teacher acts as a key person in any classroom, this study attempts to investigate teacher's questions in inquiry-based chemistry classrooms.

2.0 PURPOSE OF THE STUDY

This study examines teacher talk in terms of teacher's question in chemistry lesson.

Research questions are as follows:

1. What and how are teacher's questions related to content and science process skills in chemistry lessons, both in laboratory and theory lessons?
2. What and how are the patterns of teaching sequence(s) among chemistry teachers?

3.0 METHODS

Twenty three chemistry secondary school teachers were involved in this study. Two teachers hold master degree in education, while the other teachers hold first degree in science or chemistry education. Twenty two teachers have teaching experience ranging from 1 year to 15 years, and one teacher with more than 20 years of teaching experience. Non participant observation was applied in this study. Each chemistry teacher was observed four times to ensure data validity, which is twice for laboratory and twice for theory lessons. These observations were video and audio recorded after obtaining the teachers' consent. Duration of each lesson was of 60 to 80 minutes. An observation instrument, known as Observation Instrument in Inquiry Teaching through Verbal Interaction (OIITVI) was used in this study.

OIITVI was developed based on modification of previous classroom observation instruments (Flanders, 1970; Eggleston, Galton and Jones, 1975; Mohamed Najib, 1997 and Brandon *et al.*, 2008). There are five main categories in this instrument, which includes teacher's question, teacher's statement, student's question, student's statement and silence or confusion. Time sampling for observations was three seconds interval as used in previous researches (Flanders, 1970; Mohamed Najib and Mohammad Yusof, 1994; Mohamed Najib; 1997; Tay and Mohammad Yusof, 2009). This time sampling was chosen to ensure a detail observation. Subcategories of teacher's question are shown in Table 1.

Table 1 Observation instrument in inquiry teaching through verbal interaction (OIITVI)[a]

Category			Reference
Teacher's question (Flanders, 1970; Mohd Najib, 1997; Egglestone, Galton and Jones, 1975; Brandon *et al.*, 2008)	Content	1a. to relate students' prior knowledge and lesson	Egglestone, Galton and Jones,1975; Mohd Najib, 1997
		1b. to arouse students' thinking of a concept	
		1c. to obtain meaning of a definition/principle/concept	Mohd Najib, 1997; Brandon *et al.*, 2008
	Science process skills	1d. Observing	
		1e. Classifying	
		1f. Measuring and Using Number	
		1g. Making Inferences	Egglestone, Galton and Jones, 1975, Mohd Najib, 1997
		1h. Predicting	Egglestone, Galton and Jones, 1975; Mohd Najib, 1997
		1i. Using Space-Time Relationship	
		1j. Interpreting data	Egglestone, Galton and Jones, 1975; Mohd Najib, 1997; Brandon *et al.*, 2008
		1k. Defining operationally	
		1l. Controlling variables	
		1m. Making hypothesis	Egglestone, Galton and Jones, 1975; Mohd Najib, 1997
		1n. Experimenting	Egglestone, Galton and Jones, 1975; Mohd Najib, 1997
		1o. Communicating	
	Not related to content/ Science process skills	1p. Class management	

Quantitative data obtained from OIITVI was analysed using Statistical Package for the Social Sciences (SPSS) PASW version 18.0. Data is in the form of frequency and percentage. In addition, semi-structured interviews were carried out after classroom observations. Observed chemistry lessons and interviews were transcribed verbatim to answer the research questions mentioned earlier.

■4.0 RESULTS AND DISCUSSION

This part discusses categories of verbal interaction in theory and laboratory lessons, categories of teacher's questions and pattern of teaching sequence.

4.1 Categories of Verbal Interaction in Laboratory and Theory Lessons

Overall, teacher's question contributes only 10.6% of overall verbal interaction that occurred during the laboratory lessons (see Figure 1). In theory lesson, higher percentage of teacher's question was shown in theory class, 16.7% (see Figure 2).

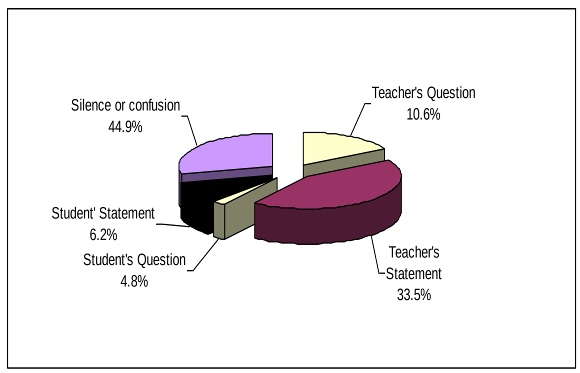

Figure 1 Verbal interaction in laboratory lessons

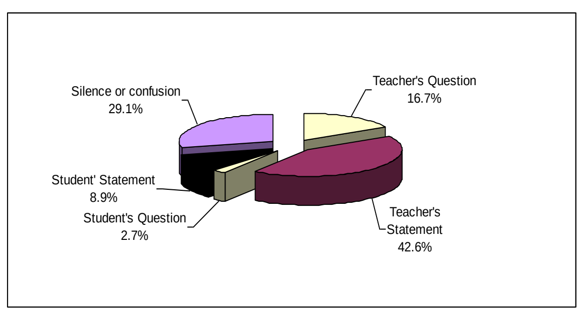

Figure 2 Verbal interaction in theory lessons

There are three main subcategories of teacher's questions; teacher's questions related to content, teacher's questions related to science process skills and teacher's questions not related to content or science process skills. In this article, only the first two subcategories will be discussed as these two subcategories are emphasised in inquiry teaching.

Table 2 Mean percentage of teacher's questions

Category	Related to content %	Related to science process skills
Mean percentage in laboratory lesson (%)	4.0	4.2
Mean percentage in theory lesson (%)	11.1	2.0

As shown in Table 2, mean percentage of teacher's questions related to content and science process skills in laboratory lessons are almost balanced. This showed that teachers emphasized both aspects of chemistry content and science process skills as required in inquiry teaching (Jadrich and Bruxvoort, 2011). However, in theory lessons, teacher's focus was more on content. In actual inquiry teaching practice, both aspects need to be emphasized in both types of lessons.

4.2 Teacher's Question Related to Content

Teachers' questions related to content are further categorised into three subcategories; teacher's questions to relate students' prior knowledge and lesson, to arouse students' thinking of a concept; or to obtain meaning of a definition/principle/concept. Based on Table 3, teacher's questions which were related to content were mainly to obtain meaning of definition, principle or concept in theory class (4.4% of the total verbal interaction). On the other hand, in laboratory class, questions were asked to arouse students' thinking of a concept (1.9% of the total verbal interaction) (see Table 3). These questions showed that chemistry teachers in this study displayed inquiry characteristics as they tried to get students' ideas on concepts discussed, especially in laboratory lessons.

4.3 Teacher's Question Related to Science Process Skills

Science process skills are prevalent in inquiry teaching as it emphasises on hands-on learning. National Research Council (2000) highlighted a few science process skills that are important, which are observing, designing experiments, analysing and interpreting data, predicting and communicating. Practices of twelve science process skills as in the chemistry specification curriculum (Curriculum Development Centre, 2005) are investigated. In laboratory class, most of teacher's questions were on experimenting, 1.91% of the total verbal interaction (see Table 4).

Table 3 Teacher's questions related to content in laboratory and theory lessons

Category	Related to content	Type of lesson	Mean (%)
Teacher's Question	1a. to relate students' prior knowledge and lesson	Laboratory	1.0
		Theory	3.0
	1b. to arouse students' thinking of a concept	Laboratory	1.9
		Theory	3.8
	1c. to obtain meaning of a definition/ principle/ concept	Laboratory	1.1
		Theory	4.4

Analysis on the transcript of the lesson showed that teachers' questions during laboratory class mostly focused on materials, apparatus and the procedure of carrying out an experiment.

Examples of questions asked were as followed:
And then you have to add how much of sodium hydroxide?
And then after heat it?
After heating?
Fifty centimetre cube of sodium hydroxide. After that, you have to?

[Respondent 07]

On the other hand, teachers tend to focus on observation skills in theory class, 0.71% of the total verbal interaction (see Table 4). Examples of questions asked were:

What is the initial colour of this magnesium ribbon?
Is there any white fume?

[Respondent 08]

Although the chemistry specification curriculum (Curriculum Development Centre, 2005) specifies practice of twelve science process skills, it is an interesting fact that there are a few chemistry teachers that were not aware of the term science process skills. This is shown in the excerpt of the interview with the teachers.

Researcher : *How about science process skills?*
Respondent 12: *What is it about? Example?*

Nevertheless, findings from this study showed that chemistry teachers in this study did focus on these skills, but the mean percentage is low. This finding suggests that chemistry educators to be aware of these science process skills and apply these skills in chemistry lessons. Next, discussion will be on the teaching pattern in chemistry lessons.

Table 4 Percentage of main subcategories in teacher's questions related to science process skills

Category	Related to science process skills	Type of lesson	Mean (%)
Teacher's Question	1d. observing	Laboratory	1.28
		Theory	0.71
	1e. classifying	Laboratory	0.07
		Theory	0.07
	1f. measuring and using numbers	Laboratory	0.28
		Theory	0.05
	1g.making Inferences	Laboratory	0.07
		Theory	0.14
	1h. predicting	Laboratory	0.02
		Theory	0.23
	1i. using space-time relationship	Laboratory	0.00
		Theory	0.00
	1j. interpreting data	Laboratory	0.36
		Theory	0.37
	1k.defining operationally	Laboratory	0.02
		Theory	0.00
	1l.controlling variables	Laboratory	0.09
		Theory	0.04
	1m.making hypothesis	Laboratory	0.06
		Theory	0.03
	1n. experimenting	Laboratory	1.91
		Theory	0.23
	1o. communicating	Laboratory	0.11
		Theory	0.09

Note: Data were reported in two decimal places to provide exact value of each subcategory

4.4 Teaching Pattern In Chemistry Lessons

Common teaching pattern in most science classrooms is IRE, which is authoritative by its nature (Scott, Mortimer and Aguiar, 2006; Sinclair and Coulthard, 1975). This pattern showed that teacher initiates by asking question, followed by response from the students and then ends with teacher's feedback. This pattern does not provide opportunities for further discussion of the questions asked, and it is more on closed chain pattern. In this study, 92 transcript lessons were analysed manually to determine the teaching sequence pattern. Although teaching pattern type 1 (IRE) showed the highest frequency (501 questions), it was found that there are other teaching patterns besides than the common IRE (see Table 5).

Table 5 Type of teacher's questions in chemistry lessons

Type	Teaching pattern	Frequency	Mean (%)
1	IRE	501	80.16
2	IE	102	16.32
3	IRIE	14	2.24
4	IR	8	1.28
Total		625	100.00

This study showed that dominance of IRE pattern in previous researches is still prevalent in chemistry lessons. Findings from this study showed that first three types of teaching sequences, which comprises of 98.72% of the teaching pattern ended with (E) evaluation from the teacher except for teaching pattern type 4. Example of the teaching patterns on one of the teaching episodes that ends with evaluation from teacher (E) is as shown below.

Teacher: Who takes these two electrons in corrosion? [I]
Student 1: Water. [R]
Teacher: The water and the? [I]
Student 1: Oxygen. [R]
Teacher: Oxygen. Yes. Ok, the water and the oxygen. [E]

This teaching pattern shown ended with evaluation from the teacher (E). This pattern, which is of closed chain do not display inquiry teaching practices. Type 4 teaching pattern could possibly trigger student's inquiry, as with no evaluation from the teacher, students are in the state of uncertainty. This will motivate them to investigate further to confirm their answer. This teaching sequence can be categorised as open chain as stated by Scott, Mortimer and Aguiar (2006). Example of excerpt of the transcript of the lesson, which displays this open chain pattern, is shown below. This excerpt shows how teachers' teaching sequence used to explore students' ideas of concept studied, rusting process.

Teacher: If the magnesium surround the whole metal, will we still have the hydroxide there? [I]
Student 1: No. [R]
Teacher: My question. Ok... my question. If magnesium surrounded the iron nail, will we still have ah… the red precipitate? [I]
Student 1: No. [R]
Teacher: Why not? [I]
Student 1: No. [R]
Teacher: Why not? [I]
Student 1: Because... oxidation. [R]
Teacher: Because oxidation? [I]
Student 2: Magnesium undergoes oxidation. [R]
Teacher: The red colour thing caused by what? [I]
Student 3: Hydroxide. [R]
Teacher: The red colour thing precipitate is caused by what? That is one of the questions here. If magnesium is being oxidized, will there any corrosion? [I]
Student 4: Yes. [R]

Furthermore, this teaching pattern showed inquiry teaching characteristics. This is due to continuous question and answer session between the teacher and student, i.e. a discussion about phenomena investigated.

Other teaching pattern, such as teaching pattern type 2, IE does not show inquiry teaching practice. In this teaching pattern, teacher asks questions, and then it was found that teacher evaluate the answer given by the students. This showed that teachers' questions were of closed-ended question which required short answer. Example from the excerpt of the transcript that showed this teaching pattern is showed below:

Teacher: So, green colour change to what colour? [I]
Teacher: Black. [E]

In inquiry teaching, teachers should remain neutral and refrain from evaluating students' answer. They should let the students in the class to decide or judge the answers (Lemke, 1990; Mortimer and Scott, 2003).

■4.0 CONCLUSION AND IMPLICATIONS TO TEACHING CHEMISTRY

Based on the findings, the emphasis given on content and science process skills in laboratory lessons are in line with National Science Education Standards (National Research Council, 2000). This is supported by Settlage and Southerland (2012), which stated that students could only learn science content with mastering the process skills. However, the findings from this study showed that there is a gap between current teaching practices with the intended inquiry practices. This has been mentioned by Keys and Bryan (2001). According to Kim *et al*. (2013), this was due to teacher's traditional practices and beliefs. IR (initiation followed by response) teaching pattern should set as an example to create inquiry among students**.** Without evaluation (E), students will be motivated to further investigate the questions asked for the answers.

Time allocated for elective science subjects, such as chemistry is four periods which is equivalent to 160 minutes per week (Ministry of Education, 1990). Based on interviews done with teachers in this study, many teachers complained of lack of time. This major barrier of implementing inquiry teaching has also been reported by Lustick (2009). If the teachers had organized and planned their lessons effectively, they could execute inquiry teaching better in the class. Teachers who are committed and disciplined enough are needed to implement this inquiry teaching in the classroom. This can only be done if teachers change their mind set and play their part in inculcating the thinking habits among students through an effective inquiry teaching. At the same time, practice of open inquiry is possible with teachers that are more open-minded as mentioned by Gengarelly and Abrams (2009). In Malaysia, Ministry of Education has long emphasized thinking habits among students through practice of higher order thinking skills (HOTS). Furthermore, this skill is one of the key attributes needed to be developed in science teaching which in line with the National Education Philosophy (Ministry of Education, 2012). This could be achieved by practicing 'correct' inquiry teaching in classroom to produce scientifically literate students in near future.

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