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Sains Humanika

A Preliminary Study of Chemistry Teachers' Question in Inquiry Teaching

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Abstract

Teachers play an important role in the teaching and learning process in science classrooms. They should be proficient in all aspects, including possess good subject content knowledge and should master the pedagogy in teaching the subject. Among the teaching methods suggested is inquiry teaching. Inquiry teaching has been widely known as one of the effective approaches in teaching science. One of the important aspects in inquiry teaching is how questions are used in classroom. In this study, teachers' question in chemistry lessons via verbal interaction has been investigated. Four chemistry teachers in secondary schools in Kuala Lumpur were involved in a preliminary study. Each chemistry teacher was observed once for a chemistry lesson of 80 minutes. Observations made were videotaped and audiotaped. An observation instrument known as Observation Instrument in Inquiry Teaching through Verbal Interaction (IPIVPI) was used in this study. Findings showed that most of the questions asked were of low level questions, which involves only cognitive memory and convergent thinking questions. Only a few questions were posed for the purpose of stimulate students' thinking and curiosity in chemistry lessons, questions on the macroscopic, sub-microscopic, symbolic as well as science process skills. This preliminary finding showed that the implementation of inquiry teaching among chemistry teachers is still in doubt. In conclusion, further research in inquiry teaching is needed to investigate this aspect of inquiry teaching in depth.

Keywords: Inquiry teaching; verbal interaction; teachers' question

Abstrak

Guru memainkan peranan penting dalam proses pengajaran dan pembelajaran sains di dalam bilik darjah. Mereka seharusnya mahir dalam segala aspek termasuklah penguasaan kandungan mata pelajaran kimia, pengetahuan yang luas dari aspek kandungan kimia dan penguasaan pedagogi bagi subjek tersebut. Antara kaedah pengajaran yang dicadangkan ialah pengajaran inkuiri. Pengajaran inkuiri merupakan satu pendekatan efektif dalam pengajaran sains. Salah satu aspek penting dalam pengajaran inkuiri ialah penggunaan soalan di dalam bilik darjah. Oleh hal yang demikian, kajian ini mengkaji soalan-soalan yang dikemukakan oleh guru kimia melalui interaksi verbal. Empat orang guru kimia sekolah menengah di Kuala Lumpur terlibat dalam kajian rintis. Pemerhatian terhadap pengajaran mata pelajaran kimia selama 80 minit dilaksanakan sekali bagi setiap orang guru. Pemerhatian tersebut dirakamkan secara audio dan video. Instrumen kajian, iaitu Instrumen Pemerhatian Interaksi Verbal Pengajaran Inkuiri (IPIVPI) digunakan dalam kajian ini. Dapatan awal kajian ini memperlihatkan bahawa kebanyakan soalan yang dikemukakan oleh guru kimia yang dikaji merupakan soalan aras rendah, iaitu soalan yang melibatkan soalan kognitif memori dan soalan berfikir konvergen. Hanya beberapa soalan guru yang bertujuan untuk merangsang pemikiran dan rasa ingin tahu pelajar, soalan mengenai aspek makroskopik, sub-mikroskopik dan simbolik serta soalan mengenai kemahiran proses sains. Hasil dapatan awal kajian menunjukkan bahawa implementasi pengajaran inkuiri dalam kalangan guru kimia masih diragui. Kesimpulannya, satu kajian yang lebih mendalam perlu dilaksanakan untuk mengkaji pelaksanaan pengajaran inkuiri guru kimia.

Kata kunci: Pengajaran inkuiri; interaksi verbal; soalan guru

1.0 INTRODUCTION

Teachers are the key to realizing curriculum aims and the quality of the science education ultimately depends on them (Asoko, 2000). In teaching science, teachers should be well verse especially the subject content knowledge, science process skills and apply suitable teaching approach. There is a wide range of teaching approaches, methods, strategies and techniques that teacher could apply in teaching. In teaching science, one of the teaching approaches that have been suggested by Curriculum Development Centre is inquiry. According to National Research Council (2000), inquiry teaching is an approach that enables students to grasps the science concepts through the process of investigation. *Pusat Perkembangan Kurikulum* (2000, 2001); Martin-Hansen (2002); Hassard (2005) and Crawford (2007) mentioned inquiry as a process to find information, to question and to investigate phenomena surrounding them. Concurrently, this teaching approach involves students to discuss and carry out hands-on activities to investigate a phenomenon.

Inquiry teaching is very important as it emphasizes the process of teaching and learning of nature of chemistry (Abrams *et al.* 2008). In addition, both content and science process skills are being emphasized. With hands-on activities, students will start 'doing' science and at the same time learning the content. Normally, science students who learn chemistry for the first time perceive chemistry as a difficult and dull subject (Tsaparlis *et al.* 2010) as they have the difficulty in understanding the link between macroscopic, microscopic and symbolic level (Johnstone, 1991, Frost and Turner, 2005). This is also mentioned by Beall, Trimbur and Weininger (1994), chemistry

bridges the boundary between the visible and the invisible. This means that in order to learn, understand and grasp concepts, there must be linkage between the macroscopic properties of matter, based on our five senses, the microscopic, which referring to the particles (atom, molecule, ion, the bonding) and the symbolic, such as the chemical formula. This is the main aspect of teaching and learning of chemistry and should be given the priority among the teachers in teaching this subject.

Studies have revealed that inquiry teaching increased the students' understanding in science (Chang and Mao, 1999; Hakkarainen, 2003). However, only a few science teachers apply inquiry teaching in the science classroom (Keys and Bryan, 2001), either in Malaysia or at other countries (Windschitl, 2003; Singer *et al*. 2005). One way to investigate the effectiveness of inquiry teaching is by investigating how teachers use questions in chemistry lessons

2.0 RESEARCH OBJECTIVE

Questioning is a vital component in teaching and learning science subjects. Teacher questioning is a common teaching tool and is very important in a lesson (Ross, Lakin and McKechnie, 2010), for example in science lesson. This is due to teacher's knowledge of the types of questions and their predicted effect on student thinking is important (Hassard and Dias, 2009). In inquiry teaching, teachers should ask questions that require higher level of thinking (Llewellyn, 2005). This is important to produce students who are able to think out of the box and not just repeating answers as in the textbook. Therefore, teachers should move towards asking questions on explanation of phenomena, rather than just asking questions for the purpose of getting the 'right answer' (Kawalkar and Vijapurkar, 2011).

Pusat Perkembangan Kurikulum has introduced this inquiry as a teaching approach since the past ten years. How effective is inquiry teaching applied by chemistry teachers? One way to investigate this is by enquire into teachers' question.

3.0 METHODOLOGY

3.1 Instrument

In this research, Observation Instrument in Inquiry Teaching through Verbal Interaction (IPIVPI) is developed based on adaptation of *Flanders' Interaction Analysis Categories* (FIAC), *Science Teaching Observation Schedule* (STOS), *Observation Schedule* and *Inquiry Science Observation Coding Sheet* (ISOCS). Teachers' question is investigated in terms of content, science process skills, and questions on classroom management. There are six categories under teachers' question related to content, that is subcategory 1a, to relate students' prior knowledge and lesson, 1b, to arouse students' thinking of a concept and 1c, to obtain meaning of a definition or principle or concept 1d, macroscopic, 1e, sub-microscopic, and 1f, symbolic. The next main category of teachers' question is related to science process skills. Subcategory 1g, teachers' question related to observing, subcategory 1h, classifying, 1i, measuring and using numbers, 1j, making inferences, 1k, predicting, 1l, using space-time relationship, 1m, interpreting data, 1n, defining operationally, 1o, controlling variables, 1p, making hypothesis, 1q, experimenting and 1r, communicating. The last subcategory 1s, allocated for teachers' question related to class management. Table 1 shows the categories in *Observation Instrument in Inquiry Teaching through Verbal Interaction* (IPIVPI).

3.2 Sample

A preliminary study has been carried out early November 2011 at three different secondary schools in Kuala Lumpur. Four Chemistry Form Four teachers have given consent to the researcher to record their teaching. Information of each chemistry teacher is shown in Table 2. The criterion for selecting the respondents is they must at least have one year experience in teaching chemistry. Each chemistry teacher was observed for an 80 minute lesson. This observation was audiotaped and videotaped.

Table 1 Categories in IPIVPI

	Category		Reference
Teachers' 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.
		1d. Macroscopic	
		1e. Sub-microscopic	
		1f. Symbolic	
	Science process skills	1g. Observing	
		1h. Classifying	
		1i. Measuring and using numbers	
		1j. Making inferences	Egglestone, Galton and Jones, 1975, Mohd Najib, 1997.
		1k. Predicting	Egglestone, Galton and Jones, 1975; Mohd Najib, 1997.
		1l. Using space-time relationship	
		1m. Interpreting data	Egglestone, Galton and Jones, 1975; Mohd Najib, 1997; Brandon *et al.*, 2008.
		1n. Defining operationally	
		1o. Controlling variables	
		1p. Making hypothesis	Egglestone, Galton and Jones, 1975; Mohd Najib, 1997.
		1q. Experimenting	Egglestone, Galton and Jones, 1975; Mohd Najib, 1997.
		1r. Communicating	
	Not related to content/science process skills	1s. Class management	
Teachers' statement (Egglestone, Galton and Jones, 1975; Mohd Najib, 1997; Brandon *et al.*, 2008).	Content	2a. To relate prior knowledge and lesson	
		2b. State the objective of the lesson	
		2c. Accept or use students' ideas	Flanders, 1970
		2d. Explanation	
		2e. Application of the concept	
	Science process skills	2f. Observing	
		2g. Classifying	
		2h. Measuring and using numbers	
		2i. Making inferences	

Table 1 Categories in IPIVPI (cont.)

Category			Reference
		2j. Predicting	Egglestone, Galton and Jones, 1975.
		2k. Using space-time relationship	
		2l. Interpreting data	
		2m. Defining operationally	
		2n. Controlling variables	
		2o. Making hypothesis	Egglestone, Galton and Jones, 1975; Mohd Najib, 1997.
		2p. Experimenting	Egglestone, Galton and Jones, 1975; Mohd Najib, 1997.
		2q. Communicating	
	Related to students' statements	2r. Praise/encourage/guide	Flanders, 1970; Mohd Najib, 1997; Brandon *et al*., 2008.
		2s.Criticize/ authority justification	Flanders, 1970
	Related to students' questions	2t. With answer	Mohd Najib, 1997
		2u. No answer	Brandon *et al*., 2008
		2v. Revert the questions to class	
		2w. Give instruction	Egglestone, Galton and Jones, 1975; Mohd Najib, 1997.
Students' questions (Flanders, 1970; Egglestone, Galton and Jones, 1975; Mohd Najib, 1997; Brandon *et al*., 2008).	Related to content/ science process skills	3a. To obtain/verify facts/ principles/ concepts.	Mohd Najib, 1997; Egglestone, Galton and Jones, 1975.
		3b. To obtain explanation of a process	Mohd Najib, 1997; Egglestone, Galton and Jones, 1975.
	Not related to content/science process skills	3c. Class management	
Students' statements (Flanders, 1970; Mohd Najib, 1997; Brandon *et al*., 2008).	Related to teachers' questions or statement	4a. With answer	Mohd Najib, 1997
		4b. No answer	
	Chemistry content	4c. To argue	
Silence or confusion (Flanders, 1970; Mohd Najib, 1997).		5a. Silence with teacher's activity / students activity (individual/group)	
		5b. Confusion	Flanders, 1970; Mohd Najib, 1997
	Wait time	5c. Wait time 1 (after teacher's question)	Rowe, 1978a, 1978b
		5d. Wait time 2 (after students' response)	

Table 2 Respondents' degree, specialisation and experience in teaching chemistry

Respondent	Degree	Specialisation	Experience in teaching Chemistry (years)
R01	Bachelor of Science with Education	Chemistry	6
R02	Bachelor of Science with Education	Chemistry	4
R03	Bachelor of Science *Kursus Perguruan Lepasan Ijazah*	Chemistry	5
R04	Bachelor of Science with Education	Chemistry/ Science	1

3.3 Data Analysis

The lesson recorded was then analyzed using IPIVPI. Each event that occurred was ticked in IPIVPI at three seconds interval to ensure a thorough analysis as suggested by Flanders (1970) and Mohd Najib (1997).

■4.0 FINDINGS AND DISCUSSIONS

In this section, teachers' question will be discussed in detail, in terms of teachers' question related to content, teachers' question related to science process skills and teachers' question on classroom management.

4.1 Teachers' Question

Overall, based on the analysis of the findings, 12.84% of the verbal interaction that occurred in chemistry lesson was teachers' question. This preliminary finding is slightly higher than the one obtained by Tay (2010), which is 11.4%.

In detail, 79.83% of the questions asked were on content, 18.44% on class management and 1.74%, on science process skills. Figure 1 shows the categories of questions used by the respondents in this preliminary study.

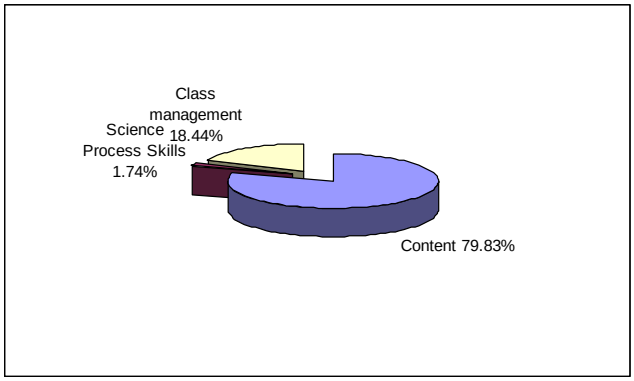

Figure 1 Main categories of teachers' question

From the findings, it can be seen clearly that teacher least emphasize science process skills. Maybe this is because the observations made were on the normal lesson, which does not involve practical or investigation.

4.1.1 Teachers' Question Related to Content

Figure 2 shows the percentage of subcategory of questions related to content.

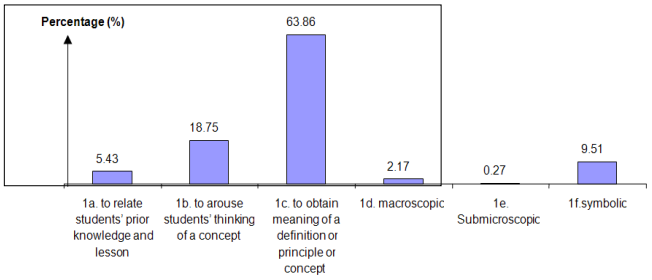

Figure 2 Subcategories of teachers' question related to content

The highest percentage of category of questions related to content is 1c, which is to obtain meaning of a definition or principle or chemistry concept, which accounts for 63.86%. Examples of questions are:

What is Haber process? (R01)

What are the reactants in this process? (R01)

What is the meaning of neutralisation? Do you understand what is metal, what is an alloy? (R04)

This is followed by questions to arouse students' thinking of a concept (18.75%). Examples of questions are:

Why the mass of ammonium sulphate obtained is less than the mass obtained theoretically? (R01)

What's so special at the bottom of your tumbler? Bottle? (R02)

We must add the lead into the glass, to give the impact of… shiny. Why? (R02)

Why it produce a very high thermal? (R02)
When you heat up this metal, what happen? (R03)

Questions on relating student's prior knowledge and lesson constitute 5.43%.

Example of questions:

When we say optical, the entire gadget like the…camera using the lens, can you give me other example of things using lens? (R02)

Meanwhile, questions on the representation levels are mainly on symbolic (9.51%). This if followed by questions on macroscopic (2.17%) and the least is questions on sub-microscopic (0.27%). Examples of questions are as below.

Ammonia is a type of gas that is alkaline with what smell is that? (R01-macroscopic)

What is the ion responsible to show an alkaline solution? (R01-sub-microscopic)

What is the formula of the salt formed? (R01-symbolic)

We got 1 mole of Na_2CO_3. So how many mole of HCl is needed? (R04-symbolic)

As mentioned earlier, there should be more emphasis on these three levels of representation, namely macroscopic, sub-microscopic and symbolic. Furthermore, there should be a linkage between these three levels of multiple representations.

This preliminary finding showed that most questions asked by chemistry teachers during are factual, and the answers are predetermined. This finding is similar with Galton *et al.* (1999), which found that most of the teachers' questions are convergent questions, for example students have to complete teacher's statement or say right or wrong. It can be seen that teachers' question place less emphasis on asking the students to think and on the nature of chemistry itself. Teachers should shift from asking cognitive memory questions such as recalling facts, rhetorical questions, which only require yes or no answer to a higher level thinking questions, by asking divergent or questions that need reasoning from the students.

4.1.2 Teachers' Question Related to Science Process Skills

Twelve science process skills as suggested by Curriculum Development Centre in Chemistry Specification Curriculum were included in IPIVPI. Figure 3 shows the percentage usage of the science process skills of the respondents in this preliminary study.

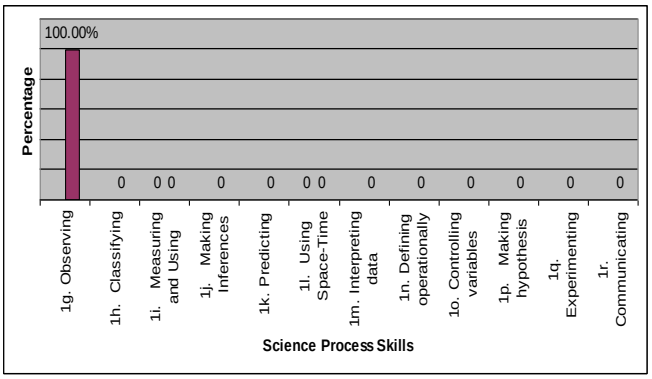

Figure 3 Subcategories of teachers' question related to science process skills

Only one out of twelve science process skills were used by these teachers, namely, observing. Most of the questions asked by these teachers are low level thinking question.
Examples of the question posed are:

Look at the window…What is the most important property for window?" (R02)

This is a spoon. What do you think? Is it a metal or alloy? (R03)

Look at the meniscus….where should we take the reading? (R04)

Teacher should ask more open questions, such as why and how based on the students' observation. If possible, they should reduce question on only asking for one predetermined correct answer, or just a yes or no answer from the student. In addition, teachers should ask questions on other high level science process skills, for example, interpreting data, experimenting and communicating.

4.1.3 Teachers' Question Related on Classroom Management

Teachers ask questions that are not related to content or science process skills are usually on classroom management. This is to make sure that the teaching and learning process run smoothly.

Examples of questions asked are:

The rest you know what to do or not? (R01).
Ok, understand? (R02)

■5.0 CONCLUSION AND IMPLICATION ON TEACHING CHEMISTRY

Chemistry is learned best when the students involved in the learning process, that is they carry out experiments or investigations, which maybe occur in the laboratory, classroom or outdoor. This is one of the conditions of inquiry teaching, which is freedom should be given to the students to design experiment to answer their own scientific questions and carry out the experiment to test their hypothesis. By using this approach, students learn by doing that is hands-on and minds-on. Therefore, teachers should inculcate the habit of asking higher level questions by asking more open and higher level questions, emphasis on the multiple levels of representations as well as science process skills to enhance students' understanding of chemistry concepts and eventually scientifically literate students are produced.

Note: There are changes on IPIVPI, after the researcher conducted the preliminary study, to enhance the thoroughness of the observation made during chemistry lesson. The author is currently conducting a research on the current inquiry teaching practices among chemistry teachers in secondary schools.

References

Abrams, E., Southerland, S., & Silva, P. (Eds.). (2008). *Inquiry in the Classroom: Realities and Opportunities*. Charlotte, North Carolina: Information Age Publishing, Inc.

Asoko, H. (2000). Learning to Teach Science in the Primary School. In R. Miller, J. Leach & J. Osborne (Eds.). *Improving Science Education: The Contribution of Research* (pp. 79–93). Buckingham: Open University Press.

Beall, H., Trimbur, J., & Weininger, S. J. (1994). Mastery Insight and the Teaching of Chemistry. *Journal of Science Education and Technology*, 3(2), 99–105.

Brandon, P.R., Taum, A. K. H., Young, D. B., Pottenger III, & Thomas, M. (2008). The Complexity of Measuring the Quality of Program Implementation with Observations: The Case of Middle School Inquiry-Based Science. *American Journal of Evaluation*, 29(3), 235–250.

Chang, C. Y., & Mao, S. L. (1999). Comparison of Taiwan Science Students' Outcomes With Inquiry-Group versus Traditional Instruction. *The Journal of Educational Research*, 92(6), 340–346.

Crawford, B. A. (2007). Learning to Teach Science as Inquiry in the Rough and Tumble of Practice. *Journal of Research in Science Teaching*, 44(4), 613–642.

Eggleston, J. F., Galton, M., & Jones, M. (1975). *A Science Teaching Observation Schedule*. London: Macmillan Education.

Flanders, N. A. (1970). *Analyzing Teaching Behaviour*. Reading, Massachusetts: Addison-Wesley Publishing Company.

Frost, J., & Turner, T. (Eds.). (2005). *Learning to Teach Science in the Secondary School: A Companion to School Experience*. 2nd ed. London: Routledge Falmer.

Galton, M., Hargreaves, L., Comber, C., Wall, D. & Pell, T. (1999). Changes in Patterns of Teacher Interaction in Primary Classroom: 1976-1996. *British Educational Research Journal*, 25(1), 23–37.

Hakkarainen, K. (2003). Progressive Inquiry in a Computer-Supported Biology Class. *Journal of Research in Science Teaching*, 40(10), 1072–1088.

Hassard, J. (2005). *The Art of Teaching Science: Inquiry and Innovation in Middle Schooland High School*. New York: Oxford University Press.

Hassard, J. & Dias, M. (2009). The Art of Teaching Science Inquiry and Innovation in Middle School. New York: Routledge.

Johnstone, A. H. (1991). Why is Science Difficult to Learn? Things are Seldom What They Seem. *Journal of Computer Assisted Learning*, 7(2), 75–83.

Kawalkar, A., & Vijapurkar, J. (2011): Scaffolding Science Talk: The Role of Teachers' Question in the Inquiry Classroom. *International Journal of Science Education*, 1–24. doi:10.1080/09500693.2011.604684.

Keys, C. W., & Bryan, L. A. (2001). Co-constructing Inquiry-Based Science With Teachers: Essential Research for Lasting Reform. *Journal of Research in Science Teaching*, 38(6), 631–645.

Llewellyn, D. (2005). *Making Inquiry Second Nature to Students: Teaching High School Science Through Inquiry*. Arlington, VA: National Science Teachers Association.

Martin-Hansen, L. (2002). Defining Inquiry. *The Science Teacher*, 69(2), 4–37.

Mohamed Najib Abdul Ghafar. 1997. *Access and Success in Higher Education*. Skudai: Penerbit Universiti Teknologi Malaysia.

National Research Council (2000). *Inquiry and the National Science Education Standards.* Washington, DC: National Academic Press.

Pusat Perkembangan Kurikulum (2000). *Huraian Sukatan Pelajaran Kimia Tingkatan Empat.* Kuala Lumpur: Kementerian Pelajaran Malaysia.

Pusat Perkembangan Kurikulum (2001). *Nota Penerangan Pusat Latihan Kursus Orientasi Sains KBSM PuLKOS Inkuiri Penemuan dalam Pengajaran dan Pembelajaran Sains*. Kuala Lumpur: Kementerian Pendidikan Malaysia.

Ross, K., Lakin, L., & Callaghan, P. (2000). *Teaching Secondary Science: Constructing Meaning and Developing Understanding*. London: David Fulton Publishers Ltd.

Rowe, M. B. (1978a). Wait, Wait, Wait…. *School Science and Mathematics*, 78(3), 207–216.

Rowe, M. B. (1978b). *Teaching Science as Continuous Inquiry: A Basic*. 2nd ed. Mc Graw Hill Company: New York.

Singer, F. M. (2001). Structuring the Information—A New Way of Perceiving the Content of Learning. *ZDM/MATHDI*, 6, 204–217.

Tsaparlis, G., Kolioulis, D., & Pappa, E. (2010). Lower-Secondary Introductory Chemistry Course: A Novel Approach Based on Science-Education Theories with Emphasis on the Macroscopic Approach, and the Delayed Meaningful Teaching of the Concepts of Molecule and Atom. *Chemistry Education Research and Practice*, 11(2), 107–117.

Tay, C. S. (2010). *Amalan Konstruktivis Guru Sains Sekolah Rendah Melalui Interaksi Verbal Bilik Darjah*. (Unpublished Doctorate Thesis). Universiti Teknologi Malaysia, Skudai, Johor.

Windschitl, M. (2003). Inquiry Projects in Science Teacher Education: What Can Investigative Experiences Reveal About Teacher Thinking and Eventual Classroom Practice? *Science Education*, 87(1), 112–143.