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Teachers' Questioning Techniques and Their Potential in Heightening Pupils' Inquiry

Omairah OMAR
Punggol Primary School

Abstract

Meaningful teaching and learning of Science stress the need for inquiry-based methods. Through effective teacher questioning techniques, these methods provide pupils with opportunities to arouse their curiosity, stimulate their imagination, and motivate them to seek out new knowledge. The Socratic method of questioning that encourages countering, analysis, and verification of information is indeed the central aspect of any classroom interaction, more so in inquiry-directed learning, as it serves so many functions. However, it is still an under-researched area in the Singaporean classroom context, encouraging the misconception among educators that echoes the conventional wisdom, "ask a higher level question at anytime, obtain a higher level answer". This study, Project *IBL Ignite*, is a professional development effort in Punggol Primary School designed to assist teachers integrate inquiry-centred Science methods in their classrooms that focuses on teachers' classroom questioning techniques (which include ample wait-time and matching pupils' readiness) and pupil inquiry. It synthesizes research findings and implications for teachers who wish to make informed choices about improving classroom questioning behaviour in the teaching of Science at the primary level. Quantitative and qualitative evaluations of the project suggest that it was generally successful in promoting positive teacher perceptions, fostering learner-centred classroom approaches, and leading to implementation of inquiry-based science in many classrooms.

Introduction

The teaching and learning of Science has indeed evolved tremendously over the past few decades. It has taken to the direction from mainly deductive teaching to inquiry-based method (NSES, 1996), in which, it has the means to increase interest in Science. The *National Science Education Standards* defines scientific inquiry as "the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural, in which pupils learn to ask questions and answer them". This "learning by doing method", in which the teacher facilitates pupils in discovering Science, stimulates the child's observation skills, imagination and reasoning capacity (Brussels, 2007).

In Singapore's Primary Science Syllabus, the inculcation of spirit of Science inquiry is central to the latest curriculum framework (MOE, 2007), where effective questioning by teachers is the catalyst in inquiry-Science learning. Questioning has a long and venerable history as an educational strategy (Cotton, 2001) and always been identified as the fundamental to outstanding teaching (Klein, Peterson, & Simington, 1991; Frazee & Rudnitski,1995; Nunan & Lamb, 1996; Hussin, H., 2006).

Questions can be effectively categorised at differing levels of Bloom's Taxonomy of School Learning (knowledge, comprehension, application, analysis, synthesis and evaluation) or simply classified as higher or lower cognitive questions. Lower cognitive questions, basically do include recalling of facts, whereas higher cognitive questions allow for pupils to mentally manipulate learnt information to create an answer (Cotton, 2001).

Effective questioning by the teacher directs pupils into understanding lesson content, arouse their curiosity, stimulate their imagination, and motivate them to seek out new knowledge. If executed skilfully, questioning would elevate pupils' level of thinking (Muth & Alverman, 1992; Orlich, Harder, Callahan, Kauchak, & Gibson, 1994; Ornstein, 1995; Hussin, H., 2006). Correspondingly, this elevates pupils' inquiry in the form of challenging assumptions and exposing contradictions that lead to acquisition of new knowledge.

Within the global and local context however, effective questioning by teachers that promotes inquiry, does not always materialise in our Science classrooms, due to time constraints and structured curriculum of subject-bound time-tabling as opposed to the more flexible, modular based and seamless classrooms. More alarmingly, educational researchers who had done extensive research on classroom questioning in inquiry-based lessons revealed that many educators who do question extensively practice the myth that advocates increasing the use of higher cognitive questions to produce superior learning gains as compared to low cognitive questions. According to *Bonwell & Eison (1991)*, techniques for more effective questioning include stating concise questions, considering a pupil's cognitive abilities when determining the level of questioning, maintaining a logical and sequential order of the questions, encouraging extension to a response, allowing sufficient time for a pupil to answer a question and encouraging the pupil to ask questions as well.

In the contrary, in the attempt of classroom questioning, teachers would also often disregard the two most crucial components of questioning - the consideration of pupils' abilities and wait-time, totally shutting off pupils' interests and inquisitiveness. This can be detrimental in the cognitive nurturing of our pupils as well as in their learning of Science, where inquiry takes the lead in preparing them for the highly unknown world of the twenty-first century. As Chaudron (1988) cautioned, poor-questioning practice can actually be counter-productive.
Wait-time is equally important as the consideration of pupils' abilities as it is a type of pause in teacher's discourse where learners have more time to process the question and formulate a

response (Chaudron, 1988; Moritoshi, P., 2001) and more learners attempt to respond (Richards and Lockhart, 1994).

Through a series of videoed and obtrusive observations, survey and analysis of three inquiry-based lessons, this paper attempts to identify the major classifications relating to teacher questions (pegged to Bloom's Taxonomy of School Learning and *Bonwell & Eison*'s techniques in effective questioning), and how these questions affect pupils' inquiry in the classroom. It also aims to confirm that if given ample wait-time and pupils' readiness are met, a higher frequency of High Order Thinking Questions (HOT) posed by a Science teacher will be positively responded with higher levels of pupils' scientific inquiry. Utilising these findings, this paper hopes to be able to enhance teachers' competency in teaching Science through inquiry.

The research question posed in this study is as follows:

To what extent do teachers' questioning techniques in P5 Science Lessons influence pupils' levels of inquiry?

Within the context of this study, *teachers' questioning techniques* is defined as the nature of questions posed by the teachers in class, as to whether these questions are Higher Order Thinking Questions (HOT) that meet pupils' readiness and scaffold pupils' thinking processes or otherwise (LOT), and *pupils' inquiry* as a set of specific behaviours suggested by the Standards-Based Science Indicators of Pupil Scientific Inquiry Behaviour. This set of behaviours includes exhibiting curiosity, pondering observations, and making connections to previously held ideas.

Method

Subjects

Two Science teachers and two intact Primary Five classes (Mixed Ability) of Punggol Primary School participated in the study. The teachers were selected based on accessibility. Their academic qualifications and training were in English and their experience of teaching Science ranged from 3 to 9 years. The two teachers took part in observations conducted throughout the study. Their selection for observation was based on the fact that they were teaching the two classes observed (5A and 5B), they were teaching the subject observed (Science), they had been trained in Science Inquiry-Based Learning, and that they had substantial experience in teaching Science, of at least three years. The two equivalent Primary 5 classes formed the pupil participants of the study. They were selected based on the grounds of similar scientific inquiry scores attained through an observation session that was conducted prior to the study. These two classes were involved in the study through observation sessions, and a perception survey.

Procedure

The study made use of the post-test only equivalent groups design. The study was conducted over a period of 8 weeks, in Terms 3 and 4 of the academic year (Diagram 1). Both classes were furnished with similar Science lesson plans that consisted of a total of nine activities. These lesson plans were based on P5 topics of Electricity (5 lesson plans) and Water (4 lesson plans) with matching specific instructional objectives as those laid out by the Primary Science Curriculum. To provide a platform for teacher questioning and pupil inquiry, these lessons were developed incalculating features of the 5Es (Engagement, Exploration, Explanation, Elaboration and Evaluation) of Science Inquiry.

The first lesson on the topic of Electricity spread over four weeks, while the remaining topic, Water, spread over the remaining four weeks. In addition, to allow for both the teachers who participated in the study to utilise the questioning platform provided by the lesson plans, they attended a comprehensive Science Inquiry-Based Workshop, followed by a series of handholding sessions in familiarizing themselves with the three lessons, which they attended prior to conducting the lessons.

The teachers executed the lessons over the same period of time, between the first week of Term 3 and eighth week of Term 4 of the school academic year, where, teachers' and pupils' were observed through video recordings and obtrusive observations by a Senior Teacher. A perception survey (Annex A), relating to classroom questioning in teaching and learning, was conducted for all participating pupils after the third lesson. Modelling after lesson study, the two teachers also met up for feedback sessions after each of their lessons to share learning points in terms of their questioning techniques and how they could further value-add pupils' inquiry through their questioning techniques in the following lesson.

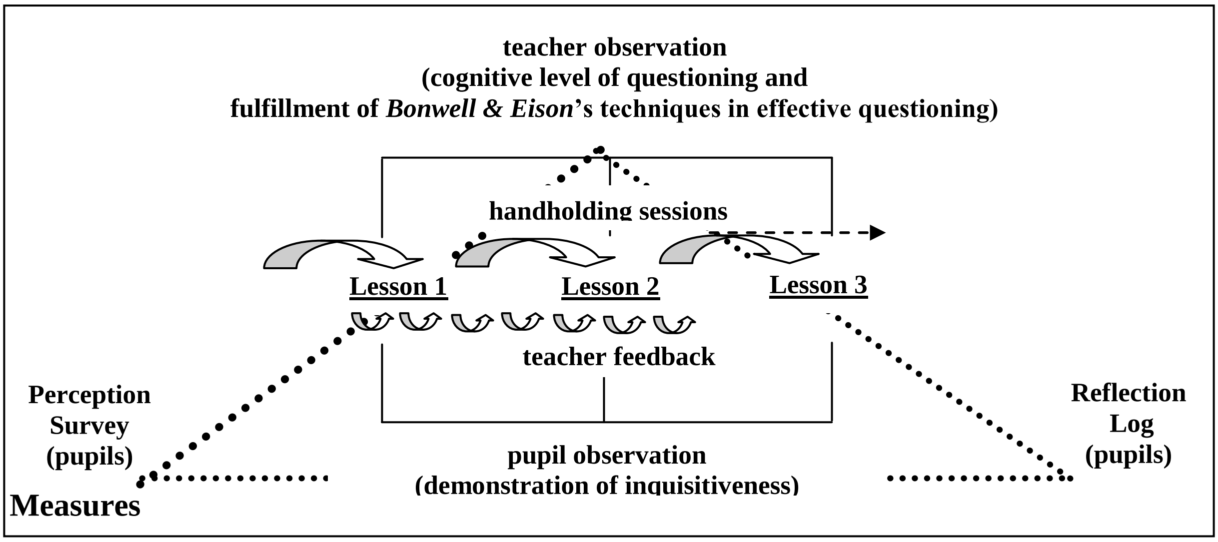


Diagram 1: An overview of the study's project design

with the purpose of capturing occurrences of the teachers' use of Higher Order Thinking Questions and pupils' inquisitive behaviour. In these observations, the Senior Teacher transcribed all the questions asked by the Science teachers, before categorising them as either High or Low Order Thinking Questions (HOT/LOT) (Annex B). To determine the nature of each of the teachers' questions, the Senior Teacher referred to a checklist that provided descriptors of the differing levels of questioning in Bloom's Taxonomy of School Learning and distinctive features of *Bonwell & Eison*'s techniques in effective questioning. A sample of the transcription is as follows:

Teacher's Transcript – Lesson One (Control Group)

What are the three states?	
When in solid what is water called?	
Why does it feel good?	
What has it got to do with the feeling of the heat on your face?	
Now, can you think of other ways to produce heat?	
What is involved in burning?	
Higher Order Thinking Questions (HOT)	**Lower Order Thinking Questions (LOT)**
Why does it feel good?	What are the three states?
What has it got to do with the feeling of the heat on your face?	When in solid what is water called?
Now, can you think of other ways to produce heat?	What is involved in burning?

The scoring of pupils' scientific inquiry were executed through pegging the evidences of pupils' scientific inquiry captured by the video recordings to a checklist adapted from *The Context for Continuous Assessment: Student Inquiry* (2006). The checklist listed twenty-six descriptors (1 point per descriptor) of Standards-Based Science Indicators of Pupil Scientific Inquiry Behaviour and had a total score ceiling of 24 (Annex C). Some examples of the listed descriptors are as follows:

Descriptors	**Score**
Pupils express ideas in a variety of ways: through journals, reporting, drawing, graphing, charting, and so on.	
They use the language used by scientists to describe their approaches to explorations and investigations.	
They describe their current thinking/theories about concepts and phenomena.	

To further validate these evidences, a survey and pupils' reflection log were used with the purpose of triangulation. All 74 pupils participated in the survey that was conducted to gather information on pupils' perceptions of the questions that their teachers asked in their Science lessons (the effect on their individual learning processes and inquisitiveness). The survey consisted of nine Likert items and four open-ended questions. Each Likert item consisted of evaluative statement about the nature of the Science teachers' questioning and a 5 response scale (Strongly Agree, Agree, Neutral, Disagree and Strongly Disagree). Questions posed in the pupil survey were based within the parameters of the research questions. Some examples of the Likert items used in the survey are as follows:

Our Science teacher gives us enough time to think about the questions he/she asked before the answer…   **1 2 3 4 5**
Most of the questions that our Science teacher asks us require us to discuss further as the answers cannot be easily found in our textbooks.   **1 2 3 4 5**

Analysis

For the purpose of analysis, all the questions posed by both teachers in the observations were transcribed, word for word, before being categorised as either High or Low Order Thinking Questions. The questions were matched against Bloom's Taxonomy's Level of Questioning, and those questions that had features similar to questions on the second level and above were categorised as High Order Thinking Questions. The evidences of pupils' scientific inquiry captured by the video recordings were matched against a checklist adapted from *The Context for Continuous Assessment: Student Inquiry* (2006). Both the project and control groups can achieve a maximum score of 24 for each observation session.

Two main statistical procedures, Cohen's Standardized Mean Difference (SMD) and Pearson's Correlation Coefficients (r), were used to analyse the findings obtained from the study. Cohen's Standardized Mean Difference was employed to measure the magnitude of the Effect Size (ES) High Order Thinking Questions posed by the teacher has on pupils' level of scientific inquiry, using the following statistical formula:

$$\textbf{Effect Size}\ (\text{ES}) = \frac{\text{Mean (project)} - \text{Mean (control)}}{\text{Standard Deviation (control)}}$$

,

In addition to this, the study also made use of Pearson's Correlation Coefficients (r) to calculate the correlation between the High Order Thinking Questions posed by the teacher and the pupils' demonstrated scientific inquiry, followed by the use of Hopkins' Values (2002) to determine the effect of the correlation.

Results

Table 1 and 2 below show the observations from the two-month study:

Table 1. Frequency of Occurrence of Teachers' HOT Questions and Pupils' Scientific Inquiry

	Frequency of Occurrences (%)			
Measure	**Lesson 1**	**Lesson 2**	**Lesson 3**	**Mean**
Teacher's HOT Qns (Exp)	46.66	23	14.28	**27.98**
Teacher's LOT Qns (Exp)	53.34	77	85.72	**24.01**
Pupils' Inquiry (Exp)	50	29.17	12.5	**30.56**
Teacher's HOT Qns (Ctrl)	12	19.05	10	**13.68**
Teacher's LOT Qns (Ctrl)	88	80.95	70	**79.65**
Pupils' Inquiry (Ctrl)	20.83	25.00	16.67	**20.83**

Table 2. Frequency of Occurrence (Project Group Over Control Group)

	Frequency of Occurrences (%)			
Measure	**Lesson 1**	**Lesson 2**	**Lesson 3**	**Mean**
Teacher's Hot Qns (Pjt)	46.66	23	14.28	27.98
Teacher's Hot Qns (Ctrl)	12	19.05	10	13.68
Exp *vs* Ctrl	**+34.66**	**+3.95**	**+4.28**	**+14.3**
Pupils' Inquiry (Pjt)	50	29.17	12.5	30.56
Pupils' Inquiry (Ctrl)	20.83	25.00	16.67	20.83
Exp *vs* Ctrl	**+29.17**	**+4.17**	**-4.17**	**+9.73**

The teacher in the project group asked more High Order Thinking Questions (46.66%) as compared to her colleague in the control group (12%). Comparatively, in terms of the frequency of occurrences, the teacher in the project class asked a mean of 14.3% High Order Thinking Questions more frequently than her colleague in the control group.

In terms of pupils' levels of scientific inquiry, the pupils' in the project group attained higher inquiry scores (50%, 29.17%, 12.5%) over the three lessons as compared to their counterparts in the control group (20.83%, 25.00%, 16.67%). The same group of pupils in the project group attained a mean inquiry score of 30.56%; 9.73% more than the score achieved by the control group. In addition to this, the pupils' in the project group demonstrated mean inquisitive behaviour 9.73% more frequently than those pupils in the control group.

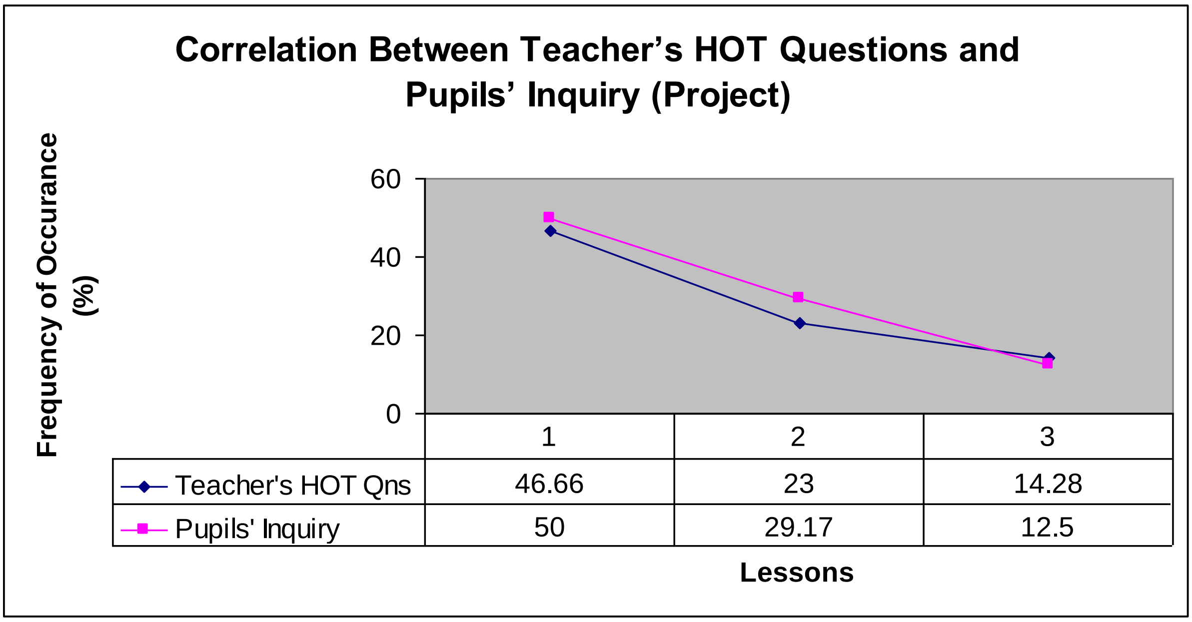
The results of measurements using Cohen's Standardized Mean Difference (SMD) to calculate the effect of teachers' High Order Thinking Questions on pupils' levels of inquiry in this study (Table 3) showed a medium effect size of 0.336645.

Table 3. Measurements using Cohen's Standardized Mean Difference (SMD)

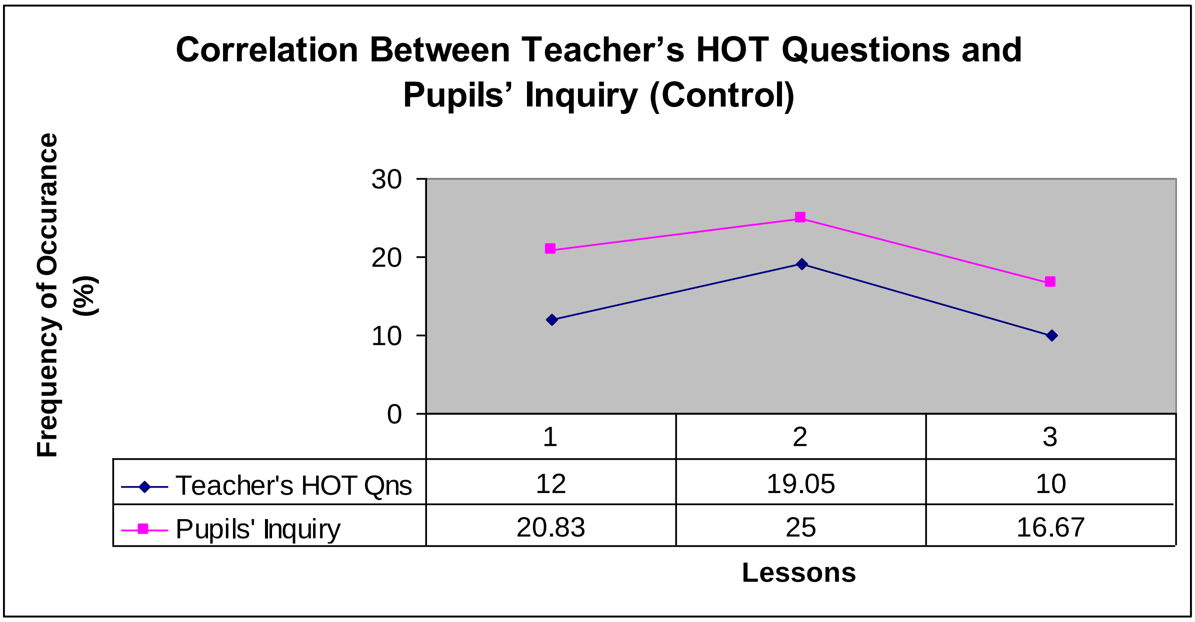
Measure (*post-test*)	**Project group (N=37)**	**Control group (N=37)**	**Effect size**	**Remarks**
Pupils' Inquiry (Behavioural)	Mean = 30.56	Mean = 20.83	-	-
	SD = 18.78842	SD = 4.165001	0.336645	Medium Effect

When plotted in a graphical form as shown below (Graphs 1 & 2), a positive correlation is evident between the amount of High Order Thinking Questions posed by the teachers and the pupils' scores in terms of scientific inquiry, both in the project and control group. Although the result was expected for the project group, it was not so for the control group.

Graph 1. Correlation Between Teacher's HOT Questions and Pupils' Inquiry (Project)



Graph 2. Correlation Between Teacher's HOT Questions and Pupils' Inquiry (Ctrl)



When measured using Pearson's Correlation Coefficients (r) to calculate the effect of teachers' High Order Thinking Questions on pupils' levels of inquiry in this study showed a very large correlation for control group (r = 0.95) and an almost perfect correlation for the project group (r = 0.98). This meant that for both the project and control groups, the greater the number of High Order Thinking Questions posed by the teacher, the level of pupils' scientific inquiry (in terms of scores) was also correspondingly elevated.

Pertaining to the issue of wait-time as discussed in the introduction above, the study recorded the teacher in the project group to have allowed an average of 1.5 minutes of wait-time after each question posed to the pupils, as opposed to the teacher in the control group, who allowed for an average of <1 minute of wait-time.

In terms of scaffolding pupils' participation through questioning, both the teachers in the observations often posed a series of question following a main question before elaborating on a pupil's answer rather than to provide answers to own questions, as follows:

T:	Why is it that it gets hotter and hotter?
T:	How do I know friction produces heat?
T:	If that is the case, I put my hands in my water bottle, do I need to shove my fingers in and rub?
T:	Why is is when I take out ice and blow at it, it doesn't melt?

A confirmatory review of the Pupil Survey revealed that both the teachers had, over the period of study, indeed frequently asked their pupils questions that required them to think; had given the pupils enough time to think about the questions before answering; and had also frequently asked questions that made the pupils want to find out more information related to the topic.

Discussion

The findings can be categorised under two main themes: teachers' questioning disposition and Pupils' Levels of Scientific Inquiry, and the positive influence of the frequency of occurrences of High Order Thinking Questions on Pupils' Levels of Scientific Inquiry.

Regardless of the lower frequency of High Order Thinking Questions in the control group, a positive correlation was observed between teachers' posed High Order Thinking Questions to pupils' level of scientific inquiry in both the project and control groups, instead of just in the expected project group. This could be due, in this study, to the high levels of teacher disposition in terms of scaffolding pupils' learning in both groups that ensured the effectiveness of utilising High Order Thinking Questions to elicit higher levels of pupil inquiry. Both the teachers' provided ample wait-time between questions (average 1.25 minutes between both the groups), and they consistently used an effective scaffolding methods in elevating their pupils' thinking processes by posing a good blend of High Order and Low Order Thinking Questions throughout the study, posing a series of questions (that their pupils' could understand and relate to), following a main question before elaborating on a pupil's answer, rather than to provide answers to their own questions. These observations affirmed *Bonwell & Eison's* theory that suggested techniques for more effective questioning should include stating concise questions (main questions in the case of the study), considering a pupil's cognitive abilities when determining the level of questioning (questions that pupils could understand, relate and respond to), maintaining a logical and sequential order of the questions, encouraging extension to a response (posing of a series of questions succeeding the main question), allowing sufficient time for a pupil to answer a question and encouraging the pupil to ask questions as well.

Another finding from the study is the greater influence that a higher frequency of occurrences of High Order Thinking Questions (along with sufficient wait-time, appropriate scaffolding etc.) within the classroom has on pupils' levels of scientific inquiry. The project group had a mean of 27.98% occurrences of High Order Thinking Questions posed by the teacher more than the control group. Interestingly, this was responded by a mean of 9.73% more occurrences of scientific inquisitiveness by the pupils in the project group when compared to the control group. This observation suggests that in any case, teachers have the ultimate power in elevating and stretching their pupils' level of scientific inquiry through manipulating the frequency of High Order Thinking Questions that they pose in any one lesson. Provided the conditions of asking effective questions is met, teachers will be able to increase the levels of their pupils' scientific inquisitiveness at any one time by simply increasing the frequency of High Order Thinking Questions in their lessons, as in the case of the teacher in the project group.

Conclusion

Within the local context, there are still many issues pertaining to teachers' questioning (in terms of the use of High Order Thinking Questions) that can be further improved on. This could be due to the teachers' assumptions that High Order Thinking Questions are only appropriate for the higher-ability classes and not so for the average classes, that they are not competent enough to execute High Order Thinking Questions skilfully, that their pupils' are not ready as Asian pupils are generally passive learners etc. The first step that schools can take to improve the current situation is to modify the current Scheme of Work into inquiry-based lessonplans for teachers to follow through. In this way, both the teachers and pupils are supplied with avenues for questioning (due to the nature of IBL lessons), which can also double up as the practising ground for questioning and a catalyst for pupils' inquiry. Given ample execution of such natured lessons, teachers' levels of confidence will also be heightened and eventually, they would be able to appropriately utilise High Order Thinking Questions within any classroom they step into.

References

Bonwell, C. & Eison, J. (1991). *Active Learning: Creating Excitement in the Classroom AEHE-ERIC Higher Education Report No.1*. Washington, D.C.: Jossey-Bass.

Chaudron, C. (1988). *Second Language Classrooms: Research on Teaching and Learning. Cambridg*e. Cambridge University Press.

Cotton, K. (2001). Close-up #5: Classroom Questioning.*Northwest Regional Educational Laboratory*. Retrieved June 14, 2008, from http://www.nwrel.org/scpd/sirs/3/cu5.html

Frazee, B., & Rudnitski, R. A. (1995). Integrated teaching methods: Theory, classroom applications, field-based connections. Albany, NY: Delmar Publishers.

Habsah Hussin. (2006). Dimensions of questioning: A qualitative study of current classroom practice in Malaysia. *TESL-EJ 10 (2).* Retrieved May 10, 2008, from www-writing.berkeley.edu/tesl-ej/ej38/a3.pdf

Klein, M. L., Peterson, S., & Simington, L. (1991). Teaching reading in the elementary grades. Massachusetts: Allyn and Bacon.

Ministry of Education of Singapore. (2007). *Primary Science Syllabus*. Ministry of Education of Singapore: Curriculum Planning & Development Division.

Moritoshi, P. (2001). Teacher questioning, modification and feedback behaviours and their implications for learner production: an action research case study. *Sanyo Gakuen University*. Retrieved May 21, 2008, from www.cels.bham.ac.uk/resources/essays/**Moritoshi**1.PDF

Muth, K. D., & Alverman, D. E. (1992). *Teaching and learning in the middle grades*. Boston: Allyn and Bacon.

Nunan, D., & Lamb, C. (1996). *The self-directed teacher: Managing the learning process*. Cambridge: Cambridge University Press.

Orlich, D. C., Harder, R. J., Callahan, R. C., Kauchak, D. P., & Gibson, H. W. (1994). *Teaching Strategies: A guide to better instruction* (4th ed.). Lexington, MA: D. C. Heath and Company.

Ornstein, A. C. (1995). *Strategies for effective teaching* (2nd ed.). Madison, WI: Brown & Benchmark.

Richards, J.C. and C. Lockhart (1994). *Reflective Teaching in Second Language Classrooms.* Cambridge: Cambridge University Press.

Appendix

<u>Annex A – Pupils' Perception Survey</u>

1.	Our Science teacher asks the class questions at all times when he/she is teaching … **1 2 3 4 5**
2.	We can understand the questions that our Science teacher asks us in Science lessons… **1 2 3 4 5**
3.	When most of us could not understand the questions our Science teacher asks, he/she would…
4.	At anytime when none of us could answer the question asked by our Science teacher, the teacher would answer the question for us. **1 2 3 4 5**
5.	When our Science teacher asks a question, many of our classmates are eager to answer the question… **1 2 3 4 5**
6.	When our Science teacher asks a question, many of our classmates are eager to answer the question because…
7.	When our Science teacher asks a question, many of our classmates are <u>NOT</u> eager to answer the question because…
8.	The questions that our teacher asks us in Science lessons need us to think… **1 2 3 4 5**
9.	Our Science teacher gives us enough time to think about the questions he/she asked before asking for the answer… **1 2 3 4 5**
10.	Most of the questions that our Science teacher asks us require us to discuss further as the answers cannot be easily found in our textbooks. **1 2 3 4 5**
11.	The questions that our teacher asks us in Science lessons help us learn new information… **1 2 3 4 5**
12.	The questions that our teacher asks us in Science lessons make us want to find out more information related to the topic… **1 2 3 4 5**
13.	When anyone of us has any questions to ask in our Science lessons, our teacher would…

Annex B – Sample Teacher's Transcription (Control, Lesson 1)

You can go into three states?
What are the three states?
What are the three states, Alan?
When in solid what is water called?
You can go into three states am I right?
What are the three states?
What have you learnt the other time?
Ok…ice..Liquid?
Now put your hands on your face. Does it feel good?
Ok Salipas says no..why?
Why does it feel good?
Okay..how does your hands feel now?
Your face feel hot right, your hands feel hot right? Why do you think their hands feel hot, Jeremy?
What is friction?
Okay..what has it got to do with the feeling of the heat on your face?
Okay..now can you think of other ways to produce heat? Anyone?
What else? Yi Ting?
Now the word burning, what is involved in burning?
So, one way to produce heat is also again to use a magnifying glass but what is the one that actually gives the heat?
How are you going to make the ice melt?
Have you found your two ways to make ice melt?
Put ice under running water. What kind of water?
Burn the ice so is it similar to putting ice over a fire?
What do you mean by burn the ice?
Put ice under the fan. So, where would your fan be?
I want to make it cooler. So how does your fan actually helps to melt your ice?
Where you get the hot air?

Higher Order Thinking Questions (HOT)	**Lower Order Thinking Questions (LOTS)**
Why do you think their hands feel hot?	What are the three states?
What has it got to do with the feelinf of the heat on your face?	When in solid what is water called?
Can you think of other ways to produce heat?	How does your hand feel now?
How does your fan actually helps to melt your ice?	What is involved in burning?

Annex B – Sample Teacher's Transcription (Project, Lesson 1)

How do we define the shape of the ice?
How many of yours is the shape of Strepsils?
Apart from shape, what else can we talk about?
Now, before the ice cubes are solid, what stage is it in?
Now, tell me why I feel warm?
These are my hands..I rub my hands together..it causes some…?
Why is it that it gets hotter and hotter?
Why does friction cause heat?
How do I know friction cause heat?
How do I know that friction produces heat?
What is the origin of heat?
How is plant able to store heat?
What is the purpose of stomata?
The energy is stored in plants. Which organism benefit from it?
What is it that you need to do to make your ice melt?
Do you think when it condenses, do you think it will be really orange juice?
When you boil soup, reaching boiling point, you put a lid on the pot, why the water will not dry up?

Higher Order Thinking Questions (HOT)	**Lower Order Thinking Questions (LOTS)**
How do I know friction cause heat?	What is the origin of heat?
Why does friction cause heat?	What is the purpose of stomata?
Why is it that it gets hotter and hotter?	Which organism benefit from it?
When you boil soup, reaching boiling point, you put a lid on the pot, why the water will not dry up?	Before the ice cubes are solid, what stage is it in?
Do you think when it condenses, do you think it will be really orange juice?	

Annex C – Observer's Checklist : Pupil's Inquiry

Inquiry/Standards-Based Science: What Does It Look Like?
Document1
Characteristics of Pupil Inquiry
Adapted from (The Context for Continuous Assesment : Student Inquiry; 2006)

1) Pupils view themselves as scientists in the process of learning

They demonstrate a desire to learn more.	
They seek to collaborate and work cooperatively with their peers.	
They are confident in doing Science: they take risks, display healthy skepticism, and demonstrate a willingness to modify ideas.	

2) Pupils accept an "invitation to learn" and readily engage in the exploration process

Pupils exhibit curiosity and ponder observations.	
They take opportunity and time to try out and persevere with their own ideas.	

3) Pupils observe.

Pupils observe carefully, as opposed to just looking.	
Pupils see details, seek patterns, detect sequences and events, notices changes, similarities and differences.	
Pupils make connections to previously held ideas.	

4) Pupils communicate using a variety of methods

Pupils express ideas in a variety of ways: through journals, reporting out, drawing, graphing, charting, and so on.	
They use the language used by scientists to describe their approaches to explorations and investigations.	
They describe their current thinking/theories about concepts and phenomena	

5) Pupils propose explanations and solutions and build a deeper understanding of science concepts

Pupils offer explanations both from their previous experiences and from knowledge and evidence gained as a result of ongoing investigations.	
Pupils use and seek evidences to justify their own and others' statements.	
Pupils sort out information and decide what is important (what does and doesn't work).	
Pupils are willing to revise explanations and consider new ideas as they gain knowledge (build understanding).	

6) Pupils raise questions

Pupils ask questions (verbally or through actions.	
Pupils use questions that lead them to investigations that generate or redefine further questions and ideas.	
Pupils value and enjoy asking questions as an important part of science.	

7) Pupils plan and carry out investigations.

Pupils design fair tests as a way to try out their ideas.	
Pupils plan ways to verify, extend or discard ideas.	
Pupils carry out investigations by handling materials with care, observing, measuring, and recording data that will allow them to develop and evaluate their explanations.	

8) Pupils critique their science practices.

Pupils create and use quality indicators to assess their work.	
Pupils report and celebrate their strengths and identify what they'd like to improve.	
Pupils reflect on their work with adults and their peers.	

Total possible score: 24
(1 point per recorded observation)

Author

Omairah OMAR
Punggol Primary School