INSIGHT INTO HOT IN A FEW MATHEMATICS CLASSROOMS IN PENANG: A SMALL CASE STUDY

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Abstract

Many teachers used questions to check their students' progress. However, some questions did not cover enough depth and breadth in most topics or subtopics. The purpose of this paper is to examine the mathematics teachers' practice of promoting High Order Thinking (HOT) skills in mathematics in four different secondary schools in one of the best states in Malaysia. The methodology used was participant observation in which 4 schools were selected within less than 10 km from Universiti Sains Malaysia, an Apex University and 9 teachers were involved as well as the number of student sample was N=221. The findings from this study involving 25 hours' video-recordings revealed that most questions used were classified as Low Order Thinking (LOT) while HOT questions came mostly from the textbooks and worksheets recommended by the ministry. The teacher's weaknesses in questioning were hidden unknowingly and obscured by the collaborative learning activities among their students.

Keywords: Low Order Thinking, High Order Thinking, questions, attitude, Collaborative Learning, metacognition

Introduction

Malaysia is a multiracial country with three main races called Malays, Chinese and Indians. According to history, the British brought Chinese and Indians in order to develop the small mining towns, plantations and estates. This created the situation of the use of more than one language in teaching and learning activities at schools before 1970s. However, beginning 1978, the Malaysian government introduced Malaysian language (Bahasa Malaysia or abbreviated as BM) to be used in all schools to create a harmonious society. In spite of that, many Chinese kept staying in urban areas for commercial reasons as well as the chances of getting the benefits of using English at schools and homes (Kamarudin Kachar, 1989; Yahaya Ismail, 1978).

Literature Review

Using more than one language in any classroom does create a few delicate problems as far as learning, teaching and understanding in mathematics and sciences are concerned. In 2003, ex-premier Tun Dr Mahathir introduced English in mathematics and science classrooms (i.e. Pengajaran dan Pembelajaran Sains dan Matematik dalam Bahasa Inggeris or abbreviated as PPSMI) but this lasted less than 10 years. He had important reasons in introducing English, one of which is to enable Malaysians to compete internationally. Poor ability of some teachers in English had somehow influenced the effectiveness of mathematics learning and teaching in some schools here.

Malaysian students at 11+ and 15+ were less competent in problem solving (Thien & Ong, 2015). So did Singapore in solving unfamiliar problems (Kaur, 2009). Unfamiliar problems covered problem solving, analysis, synthesis and evaluation and this is not easy among the teachers. One of the reasons, may be, the students were not trained systematically enough in handling problem solving that incorporates Higher Order Thinking (HOT) skills. Here HOT is defined as the potential to apply knowledge, skills and values in reasoning and reflection in order to solve problem, to make decision, be innovative and creative enough to produce something new (Ministry of Education (MOE), 2012). In Malaysia, many teachers switch code and simplify 'challenging' questions for their students (Mohd Sazali & Helmi Adly, 2012) while in America, teachers are encouraged to decide and prioritise teaching activities in their respective classrooms (Borko, Roberts, & Shavelson, 2008). Some questions that were thought to be HOT looks LOT to others and vice-versa. But some teachers knew LOT can create more active classrooms than HOT. Lack of response from students for HOT questions was probably due to unfamiliarity and inexperience that create stress and behavioural problems among students (Raths, Wassermann, Jonas, & Rothstein, 1986).

Hence the aims of this study is to investigate to what extent HOT happened in Penang mathematics classrooms as well as the depth and breadth of such thinking. This would give the readers some pictures of HOT achievement in mathematics classroom teaching and learning. It would imply and offer suggestions on how to upgrade this to produce quality students in cognition and metacognition by 2020. This paper comprises of three sections. First introduction; second methodology and results; and finally, discussions, reflections and conclusion.

Methodology

A small scale research was conducted between June and October 2015 using participant observation technique in Penang. A series of questions were collected during the 25 hours video recorded lessons observed by the researcher. These questions that were posed by nine teachers and answered by 221 students at Grade 7 as well as Grade 10 were collected and analysed. The demography of the participants is shown in Table 1 below.

Table 1
Demography of Participants in Four Selected Schools in Penang in 2015

School	Student		Teachers	Total
	Males	Females		
A	17	26	2	43
B	0	60	2	60
C	68	0	3	68
D	22	28	2	50
Total	107	114	9	221

In this study, examples of HOT (Bloom, 1956) questions; NCTM (2000) Professional Standards for Teaching Mathematics as well as Singapore Pedagogy Coding Scheme by Luke, Freebody, Cazden, and Lin (2004) are used as guideline to differentiate LOT or HOT types of questions. Some standard questions from NCTM Professional Standards for Teaching Mathematics that are used as guide are such as:

1) Knowledge (LOT): Examples are 'What is ..? Where is ..?';

2) Comprehension (LOT): Examples of questions are 'Which is the best answer? Can you explain what is meant here?';
3) Application (HOT): Examples of questions are 'What would result if ..? Can you make use of the facts to ..?';
4) Analysis (HOT): Examples are 'Why do you think...? Can you list the parts ..?';
5) Synthesis (HOT): Examples of questions are 'How would you improve...? Can you construct a model that would change ..?'; and
6) Evaluation (HOT): Examples of questions are 'What is your opinion of ..? How would you determine…?'.

Since this is a qualitative research, the coding method of analysis from 'Codes, Themes, Categories and Sub-categories' by (Saldana, 2015) was used.

Results

The results are presented in two parts: i.e. (i) Dialogues and Comments; as well as (jj) Interviews.

Part A: Dialogues and Comments

In this section, a few excerpts of dialogue from each school were produced. Categories of HOT or LOT are also attached. (Key: L3 = Line number 3)

Case 1:

In School 1, Teacher#1 was interviewed and the data were analysed in Table 2 below.

Table 2

Sample Questions Classified under LOT or HOT for Mathematics Teaching on Topic 'Cartesian Coordinates' in the First School

Type of questions	LOT	HOT
Teacher#1: You go and mark the co-ordinate E(-2,3) on the grid-board. Can?	X	
Teacher#1: See the x-axis. Where is -2 on this x-axis?	X	
Teacher#1: Let us see the answers from your friends Lim and Hanif. Here, given 2 points P(-3,5) and Q(6,5). Then the distance is ..?	X	
Teacher#1: Did you see the characteristics of points P and Q?		X
Student#5: Yes.. They are on the same y-axis that is 5 units from the x-axis. Right? OK?		
Teacher#1: How do you find the distance?		
Teacher#1: Can anybody guess any other faster method to find the distance?		X
Student#5: Just subtract teacher.		
Teacher#1: Subtract what ..?		
Student#5: 6 from -3?		

Comment_1:

The teacher was teaching with a lot of hints. The questions were mostly informative style and according to Taxonomy Bloom's stage, it is called 'Comprehension'. She kept questioning while telling and pinpointing to her students the methods used step-by-step. The only HOT question was at the point where she asked them to examine the characteristics of two points called P(-3,5) and Q(6,5) on the Cartesian Plane but this did not go beyond Bloom's stage 3 of 'Analysis'. At the point of finding distance using Pythagoras Theorem, she managed to focus

the students in the use of the theorem correctly but the way she asked did not reach Bloom Stage 4 of 'Synthesis'.

Case 2:

In School 2, Teacher#2 teaching the topic on 'Find slope or gradient' was interviewed and the data were analysed in the following Table 3.

Table 3

Sample Questions Classified under LOT or HOT for Mathematics Teaching on Topic 'Cartesian Coordinates' in the Second School

Type of questions	LOT	HOT
Teacher#2: (Two different hills called Hill 1 and Hill 2 were drawn) What did you see here?	X	
Teacher#2: I give you an example: A(3,4) and B(5, 10). The gradient is...?	X	
Teacher#2: Ok...Ok...Good …Good. Today we want to find the gradients of these 2 hills but we are using coordinates only. Gradient = 10 – 4 / (5-3) = 6/(2) = 3 (answer). (Then she explained the mechanics of finding slopes).	X	

But referring to a text-book, Teacher#2 brought the class to this point of discussion – filling up the empty table as illustrated in the following Table 4.

Table 4

Sample Demonstration to Find the Values of the Slope Given Two Points A and B.

Point A	Point B	Gradient AB
(1,2)	(4, 6)	6-2/ (4-1) = 3/3 = 1
(0,4)	(8,12)	12-4/ (8-0) = 8/8 = 1

Comment_2:

With reference to the analysis in Table 3, the teacher asked the students to fill up the rest of her questions. But the students required less effort to think when completing the sentence. Hence the questions were classified under Level 1 according to Bloom (1956), i.e. 'Knowledge'.

With reference to analysis in Table 4, firstly, the teacher failed to summarise the work of the students where all the gradients computed were equal to one. Secondly, she did not try to bring any act to introducing 'Application' (Bloom's Level 2) of mathematics using question to stimulate the students' HOT. Thirdly, she did not use this opportunity to try some questions that promote HOT related to Bloom Level 4 that is 'Analysis'. If she had let the students to relate the application of the above skill to the work of engineers in building roads along the mountainous terrains, may be the class could be better able to 'analyse' the scenario or living contexts around them and can see how mathematics can be 'applied' in the daily life.

Case 3:

In School 3, Teacher#3 teaching the topic 'Early Probability' was interviewed and the data were analysed in the following Table 5.

Table 5
Sample Questions Classified under LOT or HOT for Mathematics Teaching on Topic 'Probability' in the Third School

Type of questions	LOT	HOT
Teacher#3: Can you follow?	X	
Teacher#3: Let us use this knowledge of probability to predict his chance of winning any top price from 4-digit number, shall we?		X
Teacher#3: Did you know anybody who likes gambling in TOTO 4 digit number? Say he picked number 1001..	X	
Teacher#3: Correct! Can you explain boy? P(win) = n(1001) / n(S) which is 1/ 9999 which is about …. What everybody?		X

Comment_3:
With reference to the analysis in Table 5, it was found that the atmosphere was different here as compared to the earlier schools. There were two main reasons. Firstly, the teacher is drawing the attention to the formula on the law of chance or probability. Secondly, he asked his students to reflect and encouraged his students to think logically. The HOT question asked was: Can we predict (compute) the chance of this guy winning a TOTO number from a 4-digit number game? When he used the word predict, he demanded his students to use their past knowledge to solve the question.

Case 4:
In School 1, Teacher#4 created five groups of students randomly with questions raised to promote collaborative learning environment where HOT worksheet was distributed among the students working in groups as illustrated in the following Table 6.

Table 6
Sample Questions Classified under LOT or HOT for Mathematics Teaching with Collaborative Learning Set-up by the Second Teacher in the First School

Type of questions	LOT	HOT
Teacher#4: Ok class, I want you to spend your time discussing the questions. Before we end the class today, I want all groups to present their solutions. OK?	X	
Teacher#4: This question asked you about things from different topics. Can you guess?	X	

Comment_4 based on observation:
The Collaborative Learning groups did not have the same question to begin with. Every group has different tasks that demands different level of processes and problem solving. Therefore, the groups were not tested on HOT question at the same level.

Case 5:
In School 3, the lady Teacher#5 used ICT to encourage students to do project on topic 'Trigonometry' and the observation data were analysed in the following Table 7.

Table 7
Sample Questions Classified under LOT or HOT for Mathematics Teaching on Topic Trigonometry in a Class that Used ICT Tool in the Fourth School

Type of questions	LOT	HOT
Teacher#5: Can you prove me where I did the mistake?		X
Teacher#5: I checked the answer from the book. I realised the error. Can you help me finding the error that I had made? Anybody?		X

Here the strength of the teacher is the way she could create many interesting stories that caught the attention of her students. By the help of the computer, all of her students can see the diagrams. This was the same with the analysis of data as shown in the following Table 8.

Table 8
Sample Questions Classified under LOT or HOT for Mathematics Teaching Using the White Board Brilliantly in the Fourth School

Type of questions	LOT	HOT
Teacher#6: Can you find where the error is? (from the tree diagram)		X
Teacher#6: Exclusive event. If yes, why? And if not, why not? [HOT, Application Level]		X

Comment_5 based on observation:
Here the lady Teacher#6 managed to divide the whiteboard economically by putting her writings as neatly as possible. She spent less time in erasing her writings. The focus was to explain mutually exclusive, dependent and independent events to her probability class. At this point, the 'coding' method of analysis using Theme/Sub-themes/Categories/Sub-categories was produced as illustrated in the following Table 9.

Table 9
Analysis of Qualitative Data According to Codes, Sub-codes, Themes, Sub-themes, Categories and Sub-categories.

Theme	Sub-themes	Categories	Sub-categories
Problem Solving	Cartesian Co-ordinates	Fraction	Proper Fraction Mental Computation
Logical Thinking, Critical Thinking	Early Probability	Laws of Large numbers	Tree Diagram method

Comment_6 based on observation:
HOT questions was created among the themes and categories. Many LOT questions were produced in order to create one or two HOTs as shown in the following Table 10. A strong effort was done to analyse earlier episodes using this format. In each school, only the dialogue from first teacher was used. The effort to prepare HOT questions (in terms of the number of questions classified under the codes to promote HOT) from the four different teachers[@] (Teacher A to D) are shown in the following Table 10.

Table 10
Analysis of Number of Responses as Extracted from Excerpt of Observation Findings According to Categories and Subcategories Derived from a 30 minute Spell During a Lesson

Codes	Descriptions	Primary Documents[@]				Total number of questions
		A	B	C	D	
CC	Checking correct whether she got idea	8	13	19	12	52
EE1	Elaboration by the students themselves	12	15	11	18	56
UR1	Linking past and new ideas (skills)	10	14	12	8	44
EX	Explanation only	5	15	18	11	49
PR1	Minor probing	11	5	8	12	36
PR2	Deeper probing	9	3	2	2	16
	Total	55	65	70	63	253

[@]The documents collected from teacher (A to D) from four different schools.

A question has its own themes and categories respectively. In Table 10, each number represents 'the occurrence of a question that probes, explain, link or initiate the students to elaborate among the teams in collaborative learning set-up in order to solve a problem solving question'. Here, about 20% of the questions are probing types (PR1, PR2) which is 52 out of 253 occurrences. Most questions (49 out of 253) are to explain, checking (52 out of 253) and linking (44 out of 253) which comprises 57.3%. In other words, the teachers A to D spent three times their teaching time in helping the students to solve both HOT and LOT questions in these four different schools that act as a small sample of the teachers in Penang.

The dialogue of the first teacher from each school was categorized under 'elaboration, probing, pure description and confirming'. As reflected from the Table 10, the Teacher A has tried 8 out 55 (i.e. total times (8/55) of questioning for 'confirming' whether her students can follow her instructions. She also 'elaborated' 12/ 55 times on any particular point in her teaching. Similar was her attempt 10/ 55 to 'link' old and new knowledge in helping her students solving a question. She 'probed' 11/55 times only. Therefore according to Table 10, the four teachers (A to D) had spent a total of 52 out of 255 times of questionings on the categories of 'confirming', 56/255 times 'elaboration' and 36/255 'minor probing'. In short, the four teachers A to D had spent the most time in 'elaboration' (56/255) which is about 20% in their respective classes. This indicated that the teachers have to guide their students in solving HOT questions in their respective classes from these four different schools.

Part B: Interviews and Reflections

Interviews are incorporated in this study. This is to check the reasons for the use of certain teaching strategies. Examples are such as dialogues, transcripts and with the participating teachers' reflections as well. This is to capture whether teachers knew what they were doing according to their plans.

The following verbatim report was extracted from interview findings with R= researcher

1) Interview transcript with Teacher#3 in first school.
   R: Morning. Are you happy with your teaching just now?
   Teacher#4: Yes.
   R: Why did you say so?
   Teacher#4: I think my students could solve the problem, alright?

2) Interview transcript with Teacher#4 in the second school.
   R: I think by using the ICT, you managed to capture the students' attention. Is that what you planned earlier on?
   Teacher#4: Yes. With ICT, I can project the diagrams and the remaining time is used to ask relevant questions for the students to think, solve and discuss. Did you think.. Was it Ok?
   R: When you use the word.. prove me wrong .. you are using HOT question already.

3) Interview transcript with Teacher#5 in the third school.
   R: I think your class was a good class. Students could do the work by groups. But the group is not mixed. Indians kept to one group only. While the Chinese work with 1 or 2 Malays. Why was that arranged in collaborative learning set up?
   Teacher#5: Initially my instructions was for the students to create mix group. ..but as they went along .. they found that it was better to work with their own race.. Talk in their own language as well.
   R: I think by doing so the group is not balance. What do you think?
   Teacher#5: Yes, you are right but I think everybody wants to have their close friends to discuss.

4) Interview transcript with Teacher#8 in the fourth school.
   R: I saw you taught the angle concept very seriously today. (laugh). Is that the way you teach everyday here?
   Teacher#8: Yes. With boys, we have to be serious all the time.
   R: He..he..he … you used your actual arms to show the acute and obtuse angles. Why is that so?
   Teacher#8: More practical .., I suppose.
   R: but your questions hardly HOT type. Can you comment?
   Teacher#8: Yes I realise that… It is quite difficult to create HOT. We are in the introduction topic.

From these interviews, it can be inferred that most teachers were found to use LOT questions in the introductory parts of a lesson like How to get 45 degree angle? Can you draw one please? But at the end of the year, the teachers started to use HOT questions in the same classes, e.g. 'What is the relationship between that angle ABC with angle XBY? What facts did you use?' Besides that, the teachers started to challenge their students once the teachers felt that their students have enough knowledge to solve HOT questions.

Discussion and Recommendation

From the analysis of data as reflected in the above tables, it was found that HOT questions were not popularly used in the above schools. Among the teachers being interviewed, only one teacher had used ICT in her instructions. She projected all the questions on the whiteboard while other teachers supplied hardcopy (worksheets) to act as supplements in the classroom interactions.

Probably there are few reasons why they had focused more on LOT. In the first school, both teachers confessed that few students could solve the questions because of their background such as motivation and poor attitude in learning and this was not easy to address. Besides, LOT was simpler to attract the attention from the students. Teachers could monitor the students' interest and motivation efficiently through LOT question during the Question-and-Answer

episodes. What was seen here was that many teachers spoon fed students with knowledge as perceived to be the truth and few students dare to criticize that. They respect all knowledge as true. This finding is concurred with what Yeo and Zhu (2004) found in Singapore and what Raths et al. (1986) have discovered in America.

Secondly, there was the issue of using calculators. If students could do mental computations, may be the teachers can do more HOT activities as shown in Table 4. By using calculators, teachers lost the magic of discussing HOT question which Teacher#3 had done in a topic on 'Probability'. The beauty of 'Probability' was not so well captured in the first school as compared to other three schools and this went along with the findings by Borko et al. (2008).

Thirdly, a teacher defined HOT as a question that nobody had met before and it needs more time to solve according to the stages recommended by Bishop (2008). Another participating teacher from School 2 confessed that some teachers took some time to solve Year 9 mathematics questions themselves. This showed HOT question is quite difficult. However, some students failed to understand the core of the questions given from the workbooks. The use of two languages did not help in building HOT. This is because some time was used in translating the questions. Here the teachers kept on dwelling with LOT question first before working up towards HOT with the students. It was true and parallel to the findings by Marzita Puteh (2003) about the 'drill and practice' regime, in which some teachers focus more on short questions with mathematical facts. The teachers had used authority method to teach and this did benefit HOT since few students were willing to challenge anything from the teachers. More work needs to be done in creating confidence in trying HOT orally while technology may be used to demonstrate 'important concepts behind the theories (Yeo & Zhu, 2004). These schools had implemented Collaborative Learning strategy to enhance and enforce learning processes in their classrooms but sometimes the teachers' weaknesses in questioning were hidden during problem solving processes. This concurs with the findings by Bishop (2008) where the American teachers practice priority in the use of simpler activities before their students can solve HOT. Therefore more time is needed to train the teachers in HOT.

Conclusion

This paper reports a few significant episodes to examine HOT and LOT types of questions posed by teachers in four different schools among nine graduate teachers and the case studies were recorded in 25 hours video tapes. Most teachers used LOT rather than HOT types of question. It shows that HOT type of question needs more time for the students to think in solving any problem. Even though collaborative learning set up was used in discussing HOT problems, time and equality are not fully maximized. Although the findings cannot be too generalized for Penang schools, it is hoped that the study could provide some insights on how teachers can promote the use of HOT questions in Mathematics classroom.

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References

Bishop, A. (2008). Spatial abilities and Mathematics Education- A review. In P. Clarkson & N. Presmeg (Eds.), *Critical Issues in Mathematics Education–Major contributions of Alan Bishop* (pp. 71-81). New York: Springer

Bloom, B. S. (1956). *Taxonomy of Educational Objectives – The classification of Educational Goals – Handbook 1: Cognitive Domain*. New York: McKay.

Borko, H., Roberts, S., & Shavelson, R. (2008). Teachers' Decision Making: from Alan J. Bishop to Today. In P. Clarkson & N. Presmeg (Eds.), *Critical Issues in Mathematics Education–Major contributions of Alan Bishop* (pp. 37-67). New York: Springer.

Kamarudin Hj. Kachar. (1989). *Perkembangan Pendidikan di Malaysia.* Kuala Lumpur: Teks Publishing Sdn. Bhd.

Kaur, B. (2009). Performance of Singapore students in Trends in International Mathematics and Science studies (TIMSS). In K. Y. Wong, P. Y. Lee, Kaur, B., P. Y. Foong, & S. F. Ng. (Eds.), *Mathematics education: The Singapore journey* (pp. 439-463). Singapore: World Scientific

Luke, A., Freebody, P., Cazden, C., & Lin, A. (2004). *Singapore Pedagogy Coding Scheme*. Singapore: CRPPS.

Marzita Puteh. (2003). *Anxiety in Mathematics Teaching*. Tanjung Malim: UPSI.

Ministry Of Education (MOE), Malaysia (2012). *Malaysia Education Blueprint – A preliminary report*. Putrajaya: MOE.

Mohd Sazali Khalid & Helmi Adly M. Noor (2012). *Teaching and learning mathematics using CDiCL: Sense making through computers within teamwork*. Batu Pahat: UTHM.

NCTM. (2000). *Principle and standard for school mathematics*. Reston, VA: NCTM.

Raths, L. E., Wassermann, S., Jonas, A., & Rothstein, A. (1986). *Teaching for thinking* (2nd ed.). New York: Teachers College Press.

Saldana, J. (2015). *Fundamentals of Qualitative Research: Understanding Qualitative Research*. Oxford: Oxford University Press.

Thien, L. M., & Ong, M. Y. (2015). Malaysian and Singaporean students' affective characteristics and mathematics performance: Evidence from PISA 2012. *Springer Plus*, 4, 563.

Yahaya Ismail. (1978). *Masalah Melayu Pulau Pinang*. Kuala Lumpur: Dinamika Kreatif.

Yeo, S. M., & Zhu, Y. (2004). *Higher Order Thinking in Singapore Mathematics Classroom*. Paper presented in Conference on Redesigning Pedagogy: Research, Policy and Practice, National Institute of Education, Singapore.