

Examining the Changes in Novice and Experienced Mathematics Teachers' Questioning Techniques Through the Lesson Study Process

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The purpose of this study was to examine the changes in novice and experienced mathematics teachers' questioning techniques. This study was conducted in Sarawak where ten (experienced and novice) teachers from two schools underwent the lesson study process for fifteen months. Four data collection methods namely, observation, interview, lesson plans and journal writings were used for this qualitative case study. Graesser, Person and Huber's (1992) questioning techniques was used to categorise and analyse the questions that the participants employed. The study found that the experienced mathematics teachers moved away from routine factual questions which focused on procedures and final answers which were used in the beginning and by the end of the study, they were able to generate questions to probe the pupils' thinking. They used more probing and guiding questions and began to plan their questions that they wanted to ask. In that way, they worked towards reducing pupils' misconceptions through rich scaffolding questions. Conversely, only one of the three novice teachers showed changes in his questioning techniques. He attempted some innovations with the support and guidance of the participants. However, the other two novices showed a lack of confidence to change. Hence, it can be concluded that changes gradually took place over multiple lesson study cycles as the participants built mathematical knowledge and questioning techniques.

Keywords: Lesson Study; Questioning techniques; Experienced teachers; Novice teachers; Professional development

Introduction

Skemp (1993) aptly argued that "...the learning of mathematics, especially in its early stages and for the average pupils is very dependent on good teaching. Now to know mathematics is one thing and to be able to teach it and to communicate it to those at a lower conceptual level- is quite another matter, and I believe that it is the latter which is most lacking at the moment" (p. 34). Ma (1999) in her studies comparing United States of America (USA) and Chinese teachers noted that the USA mathematics teachers ranging from novice to experienced teachers lacked a deep conceptual understanding of many areas covered in the elementary mathematics syllabus.

The statistics from the Ministry of Education in 2006 showed that 4155 teachers were being trained for the *Kursus Perguruan Lepas Ijazah Mod Sepenuh Masa (KPLI)* (Post Graduate Full Time Teachers Course) a year. Moreover, the 27 Teachers' Training Institutes as of July 2007 have produced 6117 teachers. There are other programmes from local and foreign universities which were also training teachers for the 7623 schools throughout Malaysia (Ministry of Education, 2007). This showed that the number of novice teachers has increased tremendously in Malaysia although they may only represent a small percentage of the 346, 672 teachers in Malaysia. There is thus a need to explore ways and means to develop the novice teachers into experienced and expert teachers.

Crespo (2003) suggested that novice teachers may learn and construct meaning from their experiences when they are actively engaged in authentic activity that will help them to learn to think and act in a community of practice such as the Lesson Study collaboration in this study. This would help the practitioner to inquire and reflect on practice in the process. Teachers could either have a reflective conversation with themselves or with others to help support the changes in practice. Thus multiple interactions over a sustained period of time with the same pupils will provide opportunities for the teachers in the context for experimentation, reflection, and revision.

Based on Kamal (2001) and Ali's (2007) observations, questioning in the mathematics classroom does not play an important role in the Malaysian classroom. Kamal (2001), in her study of Malaysian rural school teachers observed that a traditional teaching style was still prevalent within the Malaysian classroom. She shared that "the teacher would present the day's lessons in the form of questions-answers or present a brief explanation of

the topic through examples either taken from the textbooks or workbooks, followed by drill exercises” (p. 164).

Ali’s (2007) study supported Kamal’s observation as he noted that the teachers’ questioning was dominated by uni-directional interaction between teachers and pupils, whereby teachers always asked the questions and pupils answered them. He established that the reasons for asking questions were to check for understanding and frequently these simple questions required short answers. Ali (2007) further expressed his concern that the type of knowledge gained from such questions may not support the achievement of the intended Malaysian mathematics curriculum. He voiced his skepticism that the Malaysian classrooms where teaching is focused on procedural competence are falling short of the intentions encapsulated within the curriculum. He supported his conclusion with the observation that classroom interaction was almost always closed and generally procedural and there was no substantive evidence to indicate that the teachers elaborated upon the children’s responses, therefore there was no interaction as espoused by Dickinson (2000). He felt that “there was virtually no evidence of ‘incorrect responses’ which suggested that during the lessons children were largely responding to questions that invoked memory of past procedures” (p. 350).

Purpose of the Study

The purpose of this study was to examine the changes in both novice and experienced mathematics teachers’ questioning techniques in teaching mathematics as a result of the Lesson Study process.

Literature Review

Questioning Techniques in Lesson Study

Watanabe (2006) envisioned that when teachers start communicating by questioning specifically about, (a) the advantages of using various teaching models, (b) the potential limitations of these models, (c) the challenges they faced as they try to make sense of or use any particular model, and (d) what the teacher can do to help pupils to make better connections, then the teachers will make themselves very relevant in the classroom. He believed that when teachers communicate among themselves to help pupils by intentionally and carefully selecting models and problem contexts that would be helpful to make connections among the various meanings of the models, the teachers become focused, coherent and kept their eyes on the bigger picture.

However, Hiebert and Wearne's (1993) and Klinzing, Klinzing-Eurich and Tisher's (1985) observation that teachers rarely asked 'higher order' questions even though these have been identified as important tools in developing pupil understanding needs careful study. Mathematics teachers need to view questions from within the context of the kind of instruction that is taking place and in relation to the mathematical context. Moreover, rich questions (William, 1999) or questions that promote mathematical thinking are necessary as standard mathematical tasks can be opened up for exploration with skilful teacher questioning (Lampert, 2001). Since questioning is a way that teachers use to bring pupils around to the correct mathematical concepts and procedures through "the negation of meaning for necessary condition of learning" (Voight, 1992, p.43), it is important to emphasise teacher's questioning as a critical part of teacher's work. The act of asking a good question is cognitively demanding because it requires considerable pedagogical content knowledge and it necessitates that teachers know their learners well.

Novice and Experienced Teachers

According to Ralph (1999), there is little recent empirical evidence that investigates the development of teacher questioning techniques among novice teachers. From the literature research reviews on novice and experienced teachers, there were serious gaps in pre-service and in-service elementary teachers' understanding of elementary school mathematics (Matthews & Seaman, 2007). Fuller (1996) suggested that novice teachers had only a procedural understanding of fractions, lacking a rich understanding of the concepts associated with fractions. Zazkis and Campbell (1996) agreed that novice teachers focused almost exclusively on the procedural aspects when solving problems involving divisibility. In 1998, Adams observed that less than 30% of pre-service teachers could describe how rational, integers, naturals, real, and whole numbers were interrelated using diagrams or descriptions. Stacey and her colleagues (2001) discovered that 20% of pre-service elementary teachers did not have a good grasp of concepts related to decimals.

Lesson Study and Questioning Techniques

Lesson Study refers to school-based professional development that plays a critical role in allowing the teachers to follow through the whole process of teaching and learning, from determining the content and scope of the lesson, arranging the sequence of curriculum and finally the lesson outcome. In planning the lesson, a comfortable, collaborative group could be formed (Takahashi, 2006). Teachers could test, search or discuss the problems that pupils may face so that they would have a focused and clearer idea on developing the research lesson and writing the lesson plan for the lesson. They could delve in detail into the process of pupil learning, including possible misconceptions and mistakes and at the same time research other topics which are related to their topic. This ensures that the teaching and learning process is optimised by understanding how the child thinks and reasons, as teachers become informed about their instruction from the child's perspectives. In that way, the teachers can support and challenge one another beyond their polite conversations, perhaps through disagreeing and asking for justification of interpretations and suggestions. Furthermore, teachers can build on pupils' discoveries by selecting specific tasks and facilitating communication to explore complex mathematics (Behrend & Mohs, 2005).

Lesson Study can change mathematics teachers' questioning techniques and this view is supported by many researchers who advocated Lesson Study as a promising model for teacher development that could bridge the endemic divide between theory and practice by supporting the teachers' learning in and from practice (Ball & Evens, 2004; Lewis & Tsuchida, 1998; Lim & Wun, 2003; Stigler & Hiebert, 1999; White & Southwell, 2003; Yoshida, 1999).

Takahashi (2006) shared that in Lesson Study, knowledgeable others can bring new perspectives and help teachers investigate a variety of materials to develop lesson plans for research lessons. For example, teachers need to have prior knowledge of the lesson, and how to relate the rationale of the lesson to the concepts and skills that pupils need or already have learned. Teachers can compare ways to help pupils accomplish the objective of the mathematics lesson by asking why and how they teach in this manner and what pupils can learn from the lesson (Takahashi, 2006, Isoda, 2006). Clarke and Hollingsworth (2002) shared the same observation that a teacher's

professional growth is through the evolving process of enacting and reflecting on the lessons. This is followed by them articulating and re-conceptualising their pedagogical epistemologies within a collaborative framework, whereby they can share ways of thinking, communicating and reflective teaching.

Teachers' questioning skills can also be tracked by using some indicators like, "Can you draw, explain, or write about your thinking and solutions?", "Will your solution always work?" (Justifying); "Will your solution work only in some circumstances?" (trial-and-error), "Can the pupils be taught to question each other?", and "Did you provide opportunities for pupils to say they don't understand or to ask for clarification?"

Research by Jaworski (1999) on teachers showed that hard questions cause a deep level of probing into the reasons for actions, interactions, activities, decisions, and responses. When teachers delve deeply and become aware of personal theories motivating their practices, they will anticipate questions and ask their own questions. This process eventually leads to explicit forms of enquiry on the part of teachers into their own teaching by generating questions that will motivate the development of their teaching.

Moreover, Lesson Study collaboration can enhance mathematics teachers' questioning techniques through writing the lesson plan which is a critical, detailed exercise. Mathematics teachers are required to include pupils' responses to the problems asked. When they used the four-column chart, steps of the lesson sequence of tasks and key questions which they have planned enable them to think through the whole process. Specifically, the second column predicts the range of pupils' responses and the reactions that the teacher might expect from each of the steps. This would force the teacher to think through the sequence of the development of the lesson. In addition, the third column will remind the teacher why a task is included and explain what the teacher is working towards. Meta cognitive analysis could then be initiated (Shimizu, 1999; Stevenson & Nerison-Low, 2002, Fernandez & Chokshi, 2002).

Clarke (2006) and Isoda (2006) explained that the level of questioning and the kinds of questions that could be asked as well as questions like “so now what?” will be able to extract pupils’ ideas and their reactions towards these ideas. Furthermore, how teachers pose a question and throw back questions, for the purpose of achieving improvement when there are inadequate points or when points in which sufficient results are not obtained in classroom instruction, may help teachers to focus on how to get the pupils to make progress. In the Lesson Study process, posing questions is not a one-sided affair but rather aimed at getting the teachers to react and respond, which finally leads to teacher-teachers, teachers-experts and teacher-pupil ‘dialogue’. Questioning functions to elicit and assist the teachers to connect with the acquisition of knowledge and skills and the formation of a mathematical way of thinking. In addition, the response also promotes teachers’ thinking and getting the teachers to talk with one another about their thoughts for deeper appreciation of communication among them (Okubo & Tsuji, 2006). Stigler and Hiebert (1999) observed that Japanese lessons are “structured problem-solving” and quite demanding problems are posed, therefore pupils have to discuss to invent their procedures and solutions (Miyakawa, 2006). Moreover, teachers rarely give an answer or solution to the given task or directly validate pupils’ answer. Rather, they only ask for reasons of a given answer (formulation), clarifies pupils’ statements and brings them to a common solution by respecting their ideas (Miyakawa, 2006).

Theoretical Framework

In this study, the constructivist learning theory was used to investigate questioning which is viewed as an active process in which learners construct new concepts based upon current and past knowledge. Based on what Vygotsky (1962) believed that the learning of mathematical concepts are based on two principles that is, new higher concepts can only be communicated to pupils by arranging for them to encounter a collection of examples and since these examples are mostly other concepts, these concepts must already be formed in the learner’s mind. The questioning techniques taken to scaffold pupils when constructing explanations will allow them to evaluate the quality as well as the development of their explanations (Sandoval & Reiser, 1997).

Conceptual Framework

The Lesson Study process focuses on the mathematics teachers from the mathematics department who formed the Lesson Study group which planned, taught and revised the lessons with the help of an outside expert (knowledgeable other). One mathematics teacher taught the research lesson while the rest of the team collected data focusing on the mathematics teacher's questioning techniques. After the lesson was conducted, the team discussed the lesson. The teachers then refined the lesson for the same grade in a different class for the next teaching of the Lesson Study cycle. Through this Lesson Study cycle, the process of planning, teaching and revising the lesson, the mathematics teachers were able to incorporate their reflection and what they have learned in their own classroom (Figure 1).

The questioning techniques which the Lesson Study team learned through each cycle was used to help fine-tune the research lesson as it proceeded. As the mathematics teachers revised the lesson plans and examined their own classrooms, specifically how they could use questioning techniques to elicit and engage the pupils in the mathematics lessons, they were able to consider their responses to their pupils and how to scaffold their pupils' learning process.

Through many cycles of Lesson Study, the mathematics teachers continued to re-examine their teachings in their own classroom using the lesson plans which they have developed. Subsequently, they generated more questions and reflections on how to enhance their questioning techniques.

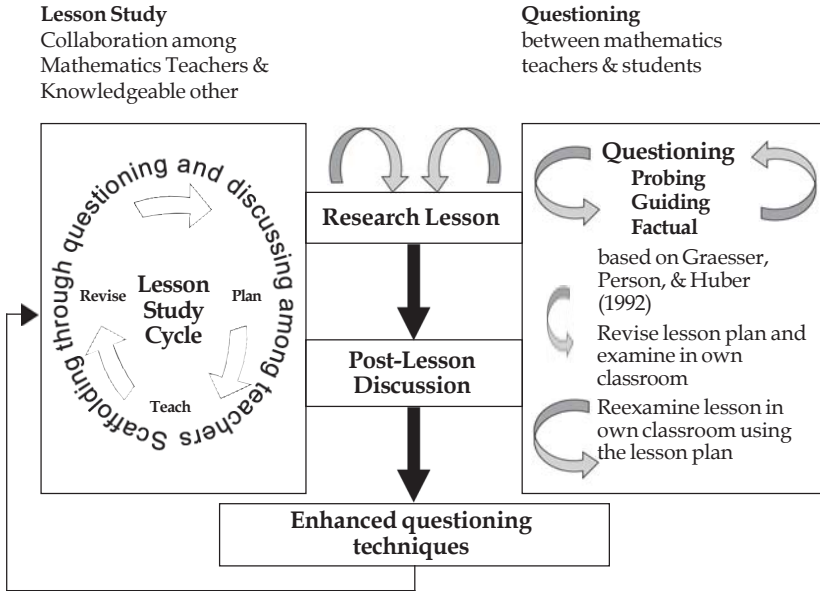


Figure 1. Conceptual framework.

Data Collection

During the fifteen months period of this study, the researcher observed both the experienced and novice teachers in a primary school (School M) and a secondary school (School P). A portion of the observations took place during mathematics instructions and also during the discussions throughout the Lesson Study process. Analysis on four experienced teachers, Cathy, Nali (School M), Wendy and Mary (School P) and three novices, Gary, Zack and Yu from School P were carried out while the other three experienced teachers left the lesson study groups after a while.

Analysis of Data

In general, this study followed the four stages of qualitative data analysis as outlined by Miles and Huberman (1994) to arrive at a conclusion. One, organising the data by reading repeatedly to familiarise the reader with the data, file the data, give reference to the data such as give codes for speakers and annotate the data as one reads it. Two, look for regularities, salient

themes or patterns of beliefs to generate categories. Annotate or mark themes in the transcript that are related to a particular category. Three, categorise the data and search for explanations of the data. Four, draw conclusions and write up the report.

Qualitative Content Analysis

In the analysis of data, the researcher used several interpretations to examine the raw data to find linkages between the participants and the outcomes with reference to the research questions. The researcher chose to remain open to new opportunities and insights by deliberately sorting the data in many different ways. This was to ensure that the researcher was able to expose and create new insights, for instance to deliberately look for conflicting data in order to expose or disconfirm the analysis. The researcher categorised, tabulated and recombined data, and finally conducted cross checks of facts especially by doing focused, short, repeated interviews with the teachers and also two sessions of interviews with the secondary pupils to verify key observations or check a fact. The researcher also randomly checked for pupils' understanding during classroom teaching.

Moreover, the researcher tabulated the number of questions asked for each category according to the Graesser, Huber and Person (1992) questioning taxonomy. This was further charted on the graph to trace the changes of questioning techniques amongst the mathematics teachers. Subsequently, the researcher transcribed the discussion and classroom teaching and placed the information in arrays of categories of similar questioning techniques in experienced and novice teachers.

Inter-Rater Reliability

The researcher asked two mathematics specialists to rate the questioning techniques to check for inter-rater reliability. Two similar classroom transcripts were given to each rater and it was discovered for Wendy's classroom teaching, the Spearman's rho is 1.0 and 0.079 for 29 items. For Nali's teaching, the correlation coefficient was 1.0 and 0.14 for 39 items.

Identifying Key Ideas

This study employed qualitative content analysis to elicit meaning from the text and to summarise the message content. The researcher began with the review of the write-up text from the field notes and the audiotapes and

videotapes and then assigned codes to pieces of text that represented either important concepts, common patterns between respondents, or direct responses by different subgroups. Themes and patterns were discovered from the characteristics of the phenomena being studied such as the questioning techniques of the mathematics teachers. The text associated with each code were then isolated and put under an assigned category.

In this step, the researcher extracted relevant and appropriate quotes or words from each transcripts and placed them under major themes of the research questions: changes in questioning techniques, weighing teaching and learning strategies, increased empathy towards their pupils' abilities, expression of "surprise", further probing of pupils, in-depth analysis of the lesson, empowering teachers' innovation, role of knowledgeable others, critiquing one another's teaching whereby the sub-themes were adapting and improving from one another, moving from politeness to professional judgment, teachers' collaboration, building a new level of trust and learning from one another across the grades. In the course of action, some data were probably ignored if deemed irrelevant in the view of the researcher.

Domain Analysis

As the quotes relevant to each theme were extracted, initial domains began to emerge from the data. The quotes were then re-examined whether they appropriately fit to the domain while new ones were created to cater for the need as it arose.

Cross-Case Analysis

In the effort to increase the validity of this study, the researcher had chosen to further use cross-case analysis. The researcher divided the data by type across all cases and examined the data thoroughly. Hence, when the pattern from one data is corroborated by the evidence from another, the finding was stronger. When evidence conflicted, deeper probing of the evidences was done to identify the cause and source of conflicts in all cases. The researcher also treated the evidence fairly to produce analytic conclusions answering the how and why of the research questions. Among the questions the researcher continuously probed whether all avenues had been explored. The researcher set clear boundaries of the case and paid special attention to conflicting propositions while critically examining the document. The researcher asked two participants, knowledgeable others and two post-

graduate students to review and comment on the draft document. Based on their comments, the researcher rewrote and made revisions.

This was to ensure that the cross case analysis could create a fully detailed and analytically rich portrayal of important processes in the changes of the teachers throughout the process of Lesson Study. Beyond that, the researcher sought to understand how mathematics teachers who were involved in this school-based professional development process collaborated with one another.

The researcher paid careful attention to the quality of evaluation to describe this project accurately so that its findings will be able to provide accurate information. In this study, the researcher had a predetermined plan to investigate the changes of questioning techniques such as probing, guiding, factual questions, differences in novice and experienced teachers' questioning techniques. However, the researcher noticed other domains had emerged from the data analysis such as "*in-depth analysis of lesson plans, role of knowledgeable others, critiquing one another.*" The researcher's next assignment was to refine these domains and cross-check to see they were appropriate. Many of these domains were interrelated and could not be differentiated with certainty; hence the data from the two schools were compared, analysed and contrasted to increase its reliability.

Findings

Some Concern on Novice Teachers' Understanding of School Mathematics

The questions that novices posed did not open opportunities for pupils to learn mathematics in a meaningful way. They did not convey implicit messages about the nature of mathematics nor engage the pupils' intellect to make connections so that they will be able to develop coherent framework for mathematical ideas. The mathematical questions posed were closed factual questions while the mathematical task focused on memorisation and procedures. Some examples of the questions can be found in Appendix A. This could be due to their own background of learning mathematics as their teachers may have been more inclined to use textbook questions. Hence novice teachers who have been under so many years of this style of mathematics education may not know how to construct mathematical questions for their pupils or ask higher level cognitive questions.

Novices seldom ask higher cognitive questions and are impatient to get the 'right' answer. They also do not vary their questioning behaviours such as using approaches other than questioning during classroom discussions (e.g., silence, making statements). They did not empower their pupils nor coax them into dialogue. Novices posed traditional single steps and computational problems but were not able to pose problems that had multiple approaches and solutions which were open-ended and exploratory and cognitively more complex.

Novices may not have adequate training to develop questioning techniques, such as asking higher cognitive questions and increasing wait time which is positively related to the achievement of pupils above the primary grades (Cotton, 2001). They did not patiently probe pupils' thinking through questioning by encouraging pupils to elaborate on their ideas. Presently, communication in the mathematics classroom seldom emphasises what is acceptable as right in the classroom through reasoning and logical arguments but rather through authority (Cheah, 2007). The novice teachers generally pose questions that focused on memorisation, procedures and tasks which require low cognitive abilities. The process of engaging pupils in connecting and doing mathematics classified as tasks of "high cognitive demand" were rare. Zack and Gary (novice teachers) also tended to reformulate questions into less demanding tasks during instruction.

Hence, we can conclude that the mathematical understanding of novice teachers may be inadequate for teaching in elementary or secondary school since their prior experiences with mathematics helped them develop knowledge which is rule bound and sparsely connected.

Differences in the Changes of Experienced and Novice Teachers

Two of the teachers, Cathy and Zack, were flexible and willing to change. They were keen to try out new techniques and spent a lot of time and thought in their preparation. Only one of the novice teachers, Zack learned to construct meaning from his experiences when he was actively engaged in authentic activity. He learned to think and act in a community of practice such as the Lesson Study collaboration. This helped him to inquire and reflect on his practice. Through reflective conversation, the Lesson Study team has helped to support the change in practice. Moreover, the multiple interactions over a sustained period of time with the same pupils have provided

opportunities to approach teaching as a context for experimentation, reflection, and revision.

At the same time, only three experienced teachers Cathy, Nali and Wendy were aware that the most routine of mathematical activities can be constructed into a worthwhile mathematical experience when posed in a way to engage the pupils in mathematics (NCTM, 2000). Cathy's fourth-grade class was challenged when they were allowed to generate and share multiple approaches to a computational problem, i.e., by using a rich task such as "how do you cut the ribbon into 8 parts? Do you fold it repeatedly? Do you have any other way to do it?"

In this study, the teachers' perceptions, weak mathematical conceptual knowledge as well as poor command of language hindered some of them in expressing, sharing, clarifying ideas, ultimately increasing reflection, development, discussion, analysis and readjustment. Although the teachers were allowed to use the English and Malay language in their interactions, Gary and Mary's poor command of the language hindered the teachers' questioning techniques. They were not able to generate ideas with expression and interpretation on what was concluded.

The novice teachers did not ask about pupils' thinking and they only directed pupils to give short correct answers. Pupils rarely made their opinions known publicly as they were not confident. The novices did not know how to interpret pupils' muttering. This study had not reached the stage whereby teachers were able to use pupils' muttering and ideas to anticipate and relate the previous lessons to the next lesson. The novices have not yet used the function of wrong answer to enhance learning.

Changes in Questioning Techniques

Ali (2007) shared that Malaysian pupils were drilled by focusing on persistent routine exercises using two different methods. The first is done by getting the pupils to recite the procedure. In the second the teacher will say the successive parts and then pupils were asked to complete the sentence. This was clearly demonstrated by Cathy and Nali in their first lessons, when Cathy introduced the word "denominator." She said the word "deno..." and then her pupils will complete it by saying "...minator" in a choral manner. Then pupils were asked to repeat the word "denominator" a few times to ascertain that they have mastered the pronunciation. Hence, the mathematics class revolved on repeated recitations. However, as the Lesson

Study progressed, the teachers worked on their questioning technique to encourage the pupils to think in a more flexible manner.

According to Ali (2007), the general consensus of teachers who were interviewed was that they faced a dilemma as the curriculum recommended conceptual teaching but they also have to delicately balance this with the demand to achieve the school targets in the examination. This again was corroborated by the participants in the Lesson Study project. Frequently the experienced teachers, like Cathy and Nali were conscious that the pupils need to understand the concept of fraction and to creatively solve different problems yet they were forced to focus extensively on ensuring the pupils master the procedural techniques used. Hence, the way they structured and presented the lesson could be at the expense of the pupils' understanding. This was clearly shown in Mary's (experienced teacher) and Gary's (novice teacher) class whereby these teachers rushed through numerous examples. In Mary's second lesson, she repeated this manner of teaching but consciously made an effort to increase pupils' interaction as well as probe them to think mathematically. However, Gary did not show any changes in his teaching from his first lesson to his third lesson. His emphasis on the drill approach was firmly entrenched as he felt his weak pupils were best suited for this manner of teaching.

There was no apparent pattern of asking particular type of questions and this was consistent with Sahin and Kulm's (2008) findings. They suggested that "probing and guiding questions are more lesson dependent than factual questions, requiring teacher to have specific knowledge and expectations of pupils' difficulties with particular content" (p. 238). However, in this study the teachers worked very hard to increase the number of questions and concentrated effort and awareness to increase guiding and probing questions, especially questions such as "why do you say so, how do you know, and why do you say yes or no" (when pupils answer in a choral manner). This is in agreement with Sahin and Kulm's (2008) assertion that when teachers have increased knowledge, their questioning technique may change.

Only Cathy and Wendy were able to use probing questions to enable their pupils to extend or generalise ideas. However, due to time constraints, Wendy finally gave up and provided the answers for her pupils. Cathy was more persistent and finally one pupil could solve her problem. Although Thompson, Philipp, Thampson and Boyd (1994) asserted that effective

questioning combined with rich dialogues precipitated significant mathematical ideas between teachers and pupils, the participants were not able to use open-ended questions to contribute in the construction of more sophisticated mathematical knowledge by pupils (Martino & Maher, 1999).

Conclusions

The Lesson Study environment helped the novices feel comfortable and safe when seeking assistance especially when they were unsure of appropriate applications. When Zack the novice was engaged in his games activities which he assumed would dramatically impact all dimensions of his teaching, he needed the nurturing environment of Lesson Study to help him to study the impact of his teaching and how to refine it and not to cast aside his new strategy. The novices did not feel isolated but rather they were able to grow professionally as seen in Zack's case.

It was difficult to get teachers to move from their often intuitive and 'normal' pattern of teaching to a different style. Hence, teachers who wanted to use higher order questions ought to see the need to do so. This was expected if they were going to invest the emotional energy that is needed to learn something new, particularly if they were already hard working teachers with not many available resources. In addition, they could also have been already burdened by doing many other things besides concentrating on teaching. They needed to see both, that there was something lacking in their teaching and that there was something they can do about it. Furthermore, the teachers needed to appreciate a different view of mathematics because if they saw mathematics as just a set of rules to learn off or even doing many exercises and getting most of them correct, they will not be able to see the need for higher order questions. On the other hand, if mathematics was seen as something to explore, create, or to investigate, then there was a role for higher order questions (Clarkson, 2008, in e-mail correspondence).

Towards the last cycle of Lesson Study, the teachers re-examined their questioning techniques and started to improvise on what they have used previously. However, there was insufficient data to suggest that they would sustain this manner of questioning techniques. In the Lesson Study process, some teachers were not fully convinced that focusing on mathematics processes was a better alternative in producing mathematical success (Cheah, 2007). Experienced teachers like Nali and Cathy have seen the need to focus on probing and asking relevant questions in order to assist the pupil move

towards solving the problem. For this reason, when the teacher probed the pupil's understanding of the problem, what the pupil knows and wants to know, they could encourage them to suggest solutions and make conjectures. They probed the pupils' thinking and thoughts, using questions to invoke their thinking until they arrived at the solution which are acceptable to the teacher.

Recommendations

Lesson Study could possibly be carried out in the Malaysian cluster schools, specifically for those with niche areas in academic achievements. As school principals have more autonomy and funding to support this professional development, they could consider whether there are other ways to produce and multiply this passion for teacher-based professional development. A sub-section of this professional development can also evaluate the assessment of mathematics teaching and mathematical thinking. The focus is basically on the lesson and how it was useful for researcher and the teachers. Some questions that can be considered are whether the questioning techniques can be linked to mathematical thinking besides identifying model teaching/questioning techniques that can be enhanced further. An add-on to the study could also investigate whether using open-ended approach has helped to generate richer mathematical task. A study on the pupils' response if the teaching and learning approach shifts from content-oriented to process-oriented can be assessed.

A study involving a few Lesson Study groups simultaneously, and also more knowledgeable others to propel or accelerate learning could be carried out. From this study, the expertise and the role of the knowledgeable others has accelerated the teachers' learning process. Likewise, expert teachers could investigate whether they could mentor and work with other mathematics teachers to develop new ideas for teaching chosen topics while investigating the curriculum, sequence and contents as well as further enhance the knowledge and skills of other mathematics teachers, specifically the novice mathematics teachers.

An investigation on novice and experienced teachers could examine a) how to pose problems in order to enhance the pupils' mathematics thinking and analyze its impact, b) how to clearly articulate what they want pupils to learn and use their prior knowledge as a potential learning trajectory, c) how to pose the main learning task such as, "Let's think about

different ways we can calculate the square", and d) at the same time observe how the pupils respond to the questions to evaluate the usefulness and appropriateness of the questions posed. Hence, this new study also could converge on more open ended questions, increasing board writing as a method to display the pupils' ideas as well as a means to summarise important ideas.

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Appendix A

Classroom Verbatim Transcripts of Experienced and Novice Teachers

Experienced Teachers	Novice Teachers
<p>Nali $\frac{1}{4}$ is $\frac{1}{2}$? Look here, can you tell me what the difference between these 2 sets of questions? (NC2)</p>	<p>Gary Find the area. (Draws rectangle) This is what? Square? Do you know the formula? How can you find the area of square? (GC1)</p>
<p>Cathy Okay, give me one example of a proper fraction. How to read this fraction? (CC1)</p> <p>How you should do, who can do this, how can you cut into six, what should you use to cut into six, (CC2)</p>	<p>What is this? (showing a picture) Tri...triangle, ok, good. How about this figure?</p> <p>Are you sure? Sure? Ok, class check? Ok, class, yes or not? (Repeat and ask again) S: No T: $65 = 34 + x$, what is your answer (GC3)</p>
<p>Wendy Today we want to find the area of a polygon. What is this? (showing a triangle). Are you sure this a right angle triangle? (teacher shows a triangle to the class)</p> <p>T: If this is not right angle triangle, how do we find the area? (WC1)</p>	<p>let's play a game together(passing out papers to students), divide into groups, this side group A and this side group B. ok, group A what is your answer? Ok, group A?</p>
<p>Rowena you said yes. How? Tell me how? Just tell me what you think/know?</p> <p>X(1,-1), Y(2,t) and Z(4,8) are lie on the same straight line, find the value of t? Using the formula, try to calculate it. Explain to me how you get the answer. You get the answer already but you don't know how to explain it.</p>	<p>Zack Ok, we are going to learn about Pythagoras theorem. Before we begin, let's play a game. The name is numbers and what is secret code. (ZC1)</p> <p>Ok, I give you this diagram to help you, what is a hypotenuse, just say whatever thing that you know, what ever it is? If wrong, I'll correct you, one word please, ok who you want to help you with this, anyone in the class, just mention the name. (ZC1)</p>

Experienced Teachers	Novice Teachers
<p>Mary Before this we have learned how to find $\sin \theta$, $\cos \theta$ and $\tan \theta$. We find $\sin \theta$, $\cos \theta$ and $\tan \theta$ from this triangle. What is the main point. How? Ok, what is the important thing you must have in the triangle? Adjacent? You must have adjacent? So, like this triangle, can we find the adjacent from this triangle (showing the equilateral triangle). Why?</p>	<p>If we want to take the first triples here, c will be 12, 5, or 13, c will be... S: 13, T: so a and b will be ... S: 5 and 12, (ZC1)</p> <p>Yu What do you notice of the two lines, which is parallel? Ok, what it means parallel? Do you still remember?</p>
