Review of Effective Teacher Questioning in Mathematics Classrooms

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Abstract

This paper reviews literature that focuses on teachers' verbal questioning within a mathematics classroom, examining the role of questions in the classroom and the extent to which this will lead to effective teaching, the significant value and gain that can be achieved by the verbal communication between teachers and students. It also explores the effects of wait time and reports on the effects from teacher questioning on gender and social class. This paper concludes with an implication and discussion to teacher questioning.

Keywords: Teacher Questioning, Effective Questioning Skills, Mathematics Classrooms.

Introduction

Teachers constantly ask questions in class, may it be verbally or in written form (for example, exercises, assessments and homework). This is a method where teachers try to investigate whether the students were listening and subsequently understand the lesson that was just taught. Watson and young (1986) stated that as many as fifty thousand questions are commonly asked by teachers in a year compared to ten questions asked by students. In a study by Leven and Long (1981), they found that high school teachers ask three to four hundred questions each day.

From the time of Plato and Socrates, and probably before, the use of questioning by teachers stimulates students' thinking in classrooms (Ellis, 1993; Wood & Anderson, 2001). The appropriate questions will help teachers and students learn from one another (Latham, 1997) and hence questioning is by far the most common verbal communication behaviours used in teaching (Ellis, 1993). Subsequently, Dymoke and Harrison (2008) further strengthened that questions posed in classrooms are seen as the backbone of communication between students and teachers. Researchers in the early 1900's started off with describing and evaluating teachers' use of questions in classrooms, then to observation and analysis of teacher questioning behaviours. Starting about 1970, researchers identified specific questioning behaviours, generally referred to as process-product research; the findings gave teachers hints on how to apply effective teaching that will contribute significant value and gains in students' achievements.

The literature reviewed for this paper will be focusing on teachers' verbal questioning within a mathematics classroom, examining the role of questions in the classroom and the extent to which this will lead to effective teaching, the significant value and gain that can be achieved by the verbal communication between teachers and students. Also, to explore the effects of wait time and reporting the effects from teacher questioning on gender and social class, this paper concludes with an implication and discussion to teacher questioning.

Review of the Literature

The role of teacher questions in a classroom setting and the significant value and gains in questioning

Martino and Maher (1994) stated that "The art of questioning may take years to develop for it requires an in-depth knowledge of both mathematics and children's learning of mathematics. Once acquired, the teacher has available a powerful tool to support students in their building of mathematical ideas" (p. 2). Many researchers believed that questioning is a vital component of helping students achieve educational objectives. Brualdi (1998) stated that in order to teach well, one must be able to question well and by asking good questions students are able to interact successfully with their teachers.

Furthermore, Rosenshine and Stevens (1986) indicated that effective teachers should ask many questions, and check for understanding frequently. Morgan and Saxton (1991) stated that teachers ask questions for several reasons:

1. the act of asking questions helps teachers keep students actively involved in lessons;
2. while answering questions, students have the opportunity to openly express their ideas and thoughts;
3. questioning students enables other students to hear different explanations of the material by their peers;
4. asking questions helps teachers to pace their lessons and moderate student behaviour;
5. questioning students helps teachers to evaluate student learning and revise their lessons as necessary.

Rose and Litcher (1998) have cited the works of Cunningham (1987), Wilen (1991) and Ellis (1993) in identifying various other reasons in addition to the five reasons above why questioning leads to learning gains. They concluded that through teacher questions students will benefit in terms of stimulation of interest in the subject, motivates student participation and requiring students to concentrate on the required tasks. Through teacher questioning teachers will be able to investigate whether students have learned and understood the material addressed by the teachers and by incorporating higher order questions, this can stimulate critical and creative thinking of the students. Furthermore, through questioning, students are able to contribute to class discussions of an issue or problem thus building up their confidence. Clearly all this has to be done with great care from the teachers so that students feel comfortable to participate. Students should not feel pressured into giving an answer but be allowed to express their views and answers.

The known fact that by asking questions, teachers know factual knowledge and conceptual understanding are transferred in this learning process (Brualdi, 1998). Although asking questions are believed to be the most influential devise in promoting learning gains, it has to be done correctly and effectively. Not only should we know what questions can be used, in addition, the types of questions teachers pose and the effective questioning techniques play a significant role in helping to create a classroom atmosphere truly conducive to developing mathematical thinking abilities (Brualdi, 1998; Burns, 1985; Ellis, 1993; Proudfit, 1992; Rose & Litcher, 1998) .

The role of teacher questions: In a mathematics classroom setting

In a mathematics classroom, one might wonder what is there to ask and when. Students spend much of their time learning arithmetic procedures and then practicing these procedures either from mathematics textbooks or worksheets that are given by their teachers. Burns (1985) and Proudfit (1992) both agreed that emphasis is often directed to getting the right answers so as to earn good grades on the tasks given. Understanding arithmetic is important if students are to become successful problem solvers and intelligent users of mathematics. Students' thinking need to be stimulated and challenged and most of all to make the students interested in the subject, "the teacher is the key to making these things happen" (Burns, 1985, p. 14). Teachers should not rely wholly on the straightforward questions from textbooks but to incorporate into the lesson solving real-world problems which does not necessarily have one correct solution. Engage students and challenge their students' thinking by focusing on the various methods of solving the problem and encourage students to supply reasoning for choosing the methods. Questions thrown to the students have to be carefully planned and the teachers themselves have to be flexible, considerate and willing to be open when addressing the different solutions to the real-world problem questions. At the same time, students need to know that their teachers do value their responses. Teachers have to emphasise that the goal is to think mathematically and to indicate to students that their responses will not be judged by just getting the correct answers.

Burns (1985) pointed out that teacher's usually only nod and affirm a students' correct response and only question the students when an error is made. Students should be made able to describe the solution no matter whether it is wrong or right and to direct the responses to the teachers and classmates to provoke class discussion. Then by discussing, not only are students urged to listen, different views will be expressed. Thus, students will gain from this experience of learning.

When should a teacher start questioning?

Nowhere in the articles reviewed does it say when will be the best time for teachers to start questioning. Teacher questioning comes naturally, may it be before, within or after the delivery of the lesson. A study by Martino and Maher (1994) examined when teacher questioning comes upon the scene but under the circumstances of students working in groups.

Martino and Maher have found that in general, students on doing a task either alone or in groups do not naturally consult themselves in seeking a justification or proof in the validity of their solutions. An additional observation within the group work confirms that students do not question each other about the details of their arguments. Wilkinson and Martino (1993) confirmed by stating that students tend to ask each other the relatively low level questions.

Hence "after students have thought of a solution, consulted with each other, and proposing that the solutions are valid and they are ready for a challenge to justify and/or generalise their solutions, it is at this time, that the teacher's role of interaction with students becomes critical" (Martino & Maher, 1994, p. 4).

The types of effective questions

The vital characteristics of a good questioning are as follows.

1. Preparing questions in advance,
2. Adapting the questions according to the skill levels,
3. The careful use of choice of words used in the questions so as to direct to all students,
4. Encouraging students in taking their time to think before answering the question,
5. Question students in a way that will make each of them wanting to reply and
6. Use the questions in gaining feedback on their learning. (McCullough & Findley, 1983).

However, Ellis (1993) argued that each type of question is effective for a particular instructional goal; it depends on the teacher on how they want to be challenged. Teachers are to clarify the instructional objectives for a particular lesson, to analyse their own students' ability levels, then plan the types of questions appropriately. In a research report by Suydam (1985), it was stated that large numbers of teachers teaching mathematics spent up to one-third of the lesson asking questions; however, 80% of the questions asked were at the knowledge and comprehension levels, that is, the lowest cognitive levels. Questions such as "What is the formula to find the area of a rectangle?" or "How do you multiply 54 and 17?" are the type of questions that primarily demands recollection of information in a recitation format. From Suydam's findings almost no questions at higher cognitive levels were asked in many classrooms where these are the types of questions that demand student to think and do real problem solving.

Referring to Martino and Maher's (1994) observation of students' group work, after the teacher listened to their students' discussion, it is at this time teacher questioning comes into action. The type of teacher question has to be connected to the students' present thinking, enabling the teacher in acquiring the students' current thinking of the mathematical idea. Martino and Maher went on to describe the types of questions that will encourage mathematical justification such as "How did you reach that conclusion?", "Could you explain to me what you did?" and "Can you convince the rest of us that your method works?" A question that students find easier in making generalisation and mathematical connections can be "Have you ever worked on a problem like this one before?"

The author would like to add that the teacher's facial expression and feeling do play an important role when questioning the types of questions specified by Martino and Maher (1994). The teacher should generate an essence of curiosity and wanting to know more; smirking and making the students feel unwanted will only put the students down and not want to participate in the future. Ellis (1993) had also listed the seven questioning behaviours that have been found to hinder and interfere with student learning. In addition, Humphrey and Milner (1998) stated,

> Students enjoy gaining access to their teacher's personality. Most students value enthusiasm, energy, and interest from their teacher. Students appreciate acknowledgement from a teacher but do not like to be watched closely. Students agree that teacher eye contact and facial expressiveness help foster good communication and relationships between teachers and students. Most students feel that good relationships with teachers positively impact their involvement and behavior in class(Humphrey & Milner, 1998, p. 74).

The majority of researchers categorised the type of questions according to the thinking levels established by Bloom and Krathwohl (1956). This typology assumes that the cognitive level of the question is determined by the students' responses requested by the teacher. Sanders (1966) have applied the Bloom's Taxonomy of thought processes at various cognitive levels to question-asking behaviour (that is, knowledge, translation, interpretation, application, analysis, synthesis and evaluation). Cunningham (1987), later reorganised these categories (the Cunningham model) into the following.

1. *Factual recall questions*, which are lowest cognitive level questions, but the type that are most frequently used in classroom interaction.
2. *Conceptual questions*, which are divided into two types of questions:
   i. Convergent questions; low-convergent questions requires students to compare, contrast, generalise, transfer, identify trends, and explain relationships. High-convergent questions are considered important for critical thinking. Students have to look for evidences and reasons to support behavioural outcomes and also to make conclusions in order to respond to a high-convergent question.
   ii. Divergent questions; low-divergent questions asks students to think of an alternate approach for a problem. Teachers use low-divergent questions as the initial step in problem-solving process. For high-divergent questions, creative thinking is encouraged, but in order for students to benefit from high-divergent questions, they should be allowed the freedom to come out with unique, new or imaginative ideas. This clearly suggests that teachers have to make the effort to give students the chance to express their responses freely and allow the exploration of ideas to flow.
3. *Evaluative or higher level questions*. Here, students are required to elaborate more on their responses by asking further why they gave such answers.

The types of questions that Barnes (1990) has identified relate directly to classroom instruction, and they are factual, reasoning and open questions. Wimer, Ridenour, Thomas and Place (2001) investigated the patterns of students' responses to higher order questioning by student gender. A higher order question that promotes analysis, synthesis and evaluation, encourages students to think critically and considered as a powerful learning tool whereas low order questions only deals with the memorisation of facts that relies on the recollection of information. Thus, Wimer and colleagues have assumed that that higher-level questioning leads to higher-level learning. Findings from Wilen and Clegg's (1986) revealed that effective teachers are more likely to ask high-level cognitive questions. Although theory strongly suggests that teachers should ask high-level questions, teachers spend most of their time asking low-level questions (Wilen, 1991; Ellis, 1993).

The effective questioning techniques

With all the research conducted in identifying question types, the next best plan is to implement them into the lesson. Teachers should be able to use effective questioning techniques that contribute to students' learning gains. Research on classroom questioning techniques can offer advice for classroom teachers in the areas of both wait time and the cognitive level of questions (Prichard & Bingaman, 1993).

Authors such as Brualdi (1998), Ellis (1993) and Rose and Litcher, (1998), except for McCullough and Findley (1983), have all listed the research conducted by Hunkins (1972), Rowe (1974a), Wilen and Clegg (1986), Wilen (1987; 1991) and AEL (1994) who have contributed to the following list of effective questioning techniques. All researchers claimed that in order to increase student learning and foster student high achievement, teachers should:

1. *Plan relevant questions*. The essence of good questioning is in planning questions that are directly related to the concept or skill being taught.
2. *Phrase questions clearly*. Clear and concise phrased questions communicate what the teacher expects of the students' responses.
3. *Ask questions at all levels*. Learning gains increase as the variety of types of questions increase. Vary the level of difficulty as to include questions on both concrete and abstract levels.
4. *Ask higher-level questions to older students*. Teachers should act as a facilitator of knowledge and ask deeper questions that will motivate their students engaging in higher-level thinking and communication.
5. *Encourage wide student participation*. Distribute questions to involve the majority of students. Balance responses from volunteering and non-volunteering students and encourage student-to-student interaction.
6. *Allow adequate wait time*. Give students time to think when responding. Allow three to five seconds of wait time after asking a question before requesting a student's response, particularly when high-level questions are asked. The more time a teacher waits for a reply from the students the better the response and will encourage other students to participate.
7. *Rephrase or redirect questions as needed*. If a student is struggling to answer a question either redirect it to another or rephrase it so it is clearer.

8. *Probe student responses in a non-judgmental way*. Ask students more questions in order to elaborate and clarify on their answer, to support a point of view, or to extend their thinking to discover new information. Teachers should also assist with student's incorrect responses.
9. *Encourage students' response*. All questions should at least be acknowledged.
10. *Provide praise and acknowledgement*. Acknowledge and emphasise correct responses and reward good answers justly.
11. *Do not repeat students' responses*. Let students have to listen for themselves.
12. *Use both covert and overt strategies*. Do not direct the question to anyone until it is asked. This forces all students to pay attention and requires more students to answer the question mentally. The initial use of covert strategies and following them with overt strategies produces active involvement and better individual responses.

McCullough and Findley (1983) summarised that after teachers have demonstrated good questioning techniques, teachers should plan for a transition that encourages students to participate in questioning and thus developing students' own use of strategy. From there, student-to student interaction are enforced hence as they solve problems and make decisions their thinking skills are developed. With students becoming comfortable in questioning themselves and others, the strategies of questioning will be useful in their everyday encounters and involvement with mathematics. According to McCullough and Findley (1983), "Good questioning techniques are a teacher's best tool to insure total class involvement and individual success" (p. 9).

The effects of wait time

It is important for teachers to allow adequate classroom time for students to consider the questions posed to them. Studies reported by Ellis (1993), Martino and Maher (1994), McCullough and Findley (1983), and Prichard and Bingaman (1993) acknowledged strongly the work of Mary Budd Rowe (1974a, 1974b, 1978 and 1986) on her research on wait time. Rowe's (1974a) earlier research has demonstrated that teachers typically wait one second or less for students' response. In Martino and Maher's (1994) study of analysing how timely questioning in stimulating justification and generalisation within third and fourth grade mathematics students found that students require sufficient time to formulate a solution to the question asked by the teacher.

Furthermore, students will give thoughtful responses and classroom discussion increases hence longer wait time leads to active student participation. Rowe (1986) has identified the following advantages and effects by increasing wait time to three seconds or more:

1. The length of student responses increases between 300 percent and 700 percent.
2. More inferences are supported by evidence and logical improvement.
3. The incidence of speculative thinking increases.
4. The number of questions asked by students increases, and, in the case of science, the number of experiments they propose increases.
5. Student-student exchanges increases; teacher-centred behaviour decreases.
6. Failures to respond decreases.
7. Disciplinary moves decrease.
8. The variety of students participating voluntarily in discussions increases. Also, the number of unsolicited, but appropriate, contributions by students increases.
9. Student confidence, as reflected in fewer inflected responses, increases.
10. Achievement improves on cognitively complex written measures. (Rowe, 1986, p. 97).

The tremendous improvement in what wait time can do is amazing, this by just telling teachers to wait a few more seconds for a student to reply. The time spent in waiting is worth the wait and is made up in the responses teachers gain by making wait time an important element in questioning.

The effects of teacher questioning on gender and social class

Do boys get questioned more than girls by their teachers in mathematics classes or vice versa? Sadker and Sadker (1994) reported that teachers do ask boys more questions than they ask girls, especially questions that involve academic content. In addition, studies by Jussim and Eccles (1992), and Kelly (1988), have suggested that teachers give more feedback to boys than to girls. When teachers were made aware of the gender-biased interactions in classroom, nothing improved (Gould, 1995).

Hendrick and Stange (1989) stated that although teachers don't show gender favouritism on a conscious level, they tend to exhibit in it in a subtle approach used with their students. Other researchers have shown that participation and access in mathematics is subject to gender (Willis, 1989) and social class (Anyon, 1981; Atweh & Cooper, 1992).

Studies by Becker (1981), Lorenz (1980), and Spender (1982) on the other hand, have described how the teachers interact differently to boys and girls in mathematics classroom. "One of the major forms of interaction from which individual learn mathematics is oral communication between teacher and students" (Cooper, Atweh, Baturo & Smith, 1993, p. 12). Evidences has emerged (Eccles & Blumenfeld, 1985; Good, Slavin, Harel & Emerson, 1987; Wilkinson & Marrett, 1985) which reports that communication between teachers and students is affected by gender, social class and teachers' perceptions of students' abilities.

Since there are evidences that suggest that boys get questioned more to girls, especially in a mathematics classroom, this will likely to cause an effect on the mathematics achievements on the female students. The second part of a two-part study conducted by Cooper *et al.* (1993) was reviewed. The purpose of the study was to identify, describe and explain the differences in the delivery of the mathematics curriculum that occurred due to gender and social class. The subjects were the teachers and students from four Year 9 mathematics classes in four single-gender private schools. The students were drawn from low socioeconomic class for boys (Oceanview), low socioeconomic class for girls (Northside), high socioeconomic class for boys (Cityview) and high socioeconomic class for girls (Hilltop). The only male teacher was from Oceanview. There were vast differences in teacher approach reported. For the low socioeconomic classes, the teacher questioning were only directed to whether students understood the lessons and the teacher would happily accept the nil response from their students.

In both high socioeconomic classes for boys and girls, the teachers tend to ask more questions regarding with their lessons. The communication in the Northside mathematics classes was mainly non-academic, the teacher answered her own questions and students gave chorused answers. Oceanview displays combative communication between teacher and students. In Hilltop, however, the students would request the teacher to give more explanation to the lesson and she would use students' answers in her teaching. A big contrast for the Cityview teacher, she would use teacher questioning of students as means of introducing new ideas and teacher-student interactions were prominent. The Cityview teacher would insist on students giving an explanation to the solution procedure and when more than one solution was possible to a particular exercise, she would ask students to evaluate the merits of each solution.

The four teachers in this study were all highly professional and caring people. The significance of the study was not to focus on the characteristics and styles of the four individual teachers but to the context of the classroom was seen as a stronger determinant of teaching behaviour. Hence, it was evident in the study that the observed variations in the four teachers' oral communication were consistent with existing stereotypes about differing needs and abilities of girls and boys and students from low and high socioeconomic backgrounds. Cityview, high socioeconomic class for boys will get high achievement in mathematics compared to the other three classes due to more teacher-student interaction and the ability for students to think further within the given tasks.

A study by Wimer *et al.* (2001) was reviewed next. This was a study specifically to explore higher order questioning in the interaction patterns of teachers and students in public and private urban schools. The purpose of this study was to investigate whether level of questioning by the teacher might differ for boys and girls. The findings from the study suggest that girls were not questioned less than the boys in urban elementary classrooms. Both genders experienced a low frequency of being asked higher order questions and boys are more likely to be called on when they do not volunteer. Although these are suggestive findings of gender patterns, it was concluded from the study that no gender difference exist in students' responses to the higher order questioning. The minimum use of higher order questions in classrooms by the 16 teachers was also noted.

Discussion

Back in the author's primary and high school years, teachers will only question the students after giving the lesson of the day, and since teachers are seen as an authority figure, students are scared to raise their hands to ask a question. Being nervous when it is your time to answer the question is common, the teacher absolutely made no effort in making the environment comfortable for the students and at no stage has the desire to know more from the students' replies. These factors greatly hinder student's learning.

The differences in written form questioning to oral teacher questioning are; oral teacher questioning encourages all students to participate in class discussion. Classroom interaction occurs between the student, his/her other classmates and the teacher. Students will share their views, thinking and procedures to either a low or high problem-solving task.

So what has teacher questioning to do with students passing an examination? The author believes that a student's achievement doesn't just rely on enough practice to various written exercises. If a student understood the lesson that was just taught and the teacher has achieved this by asking questions in class which promotes independent student thinking and involving students in an interactive learning process, therefore within the examination, the students will be able to recall and think back the steps that were discussed in class.

Research findings have shown that effective questioning skills have been linked with students' achievement in mathematics. It is the teacher's main criteria to ensure that they become effective teachers by asking higher level process-type questions in class. Allow students to explain and elaborate more on the correct answers given and encourage students to ask questions back to the teachers. Using questions as part of a tool in teaching will motivate and challenge students and moreover, promotes classroom interaction.

Finally to summarise teacher questioning in mathematics classroom, to be an effective teacher, one should ask effective questions with the use of appropriate high order teacher questions, remember to wait for a few seconds in order to get thoughtful responses from students, structure the teacher questions in ensuring wider class participation, be flexible, open and non-judgmental towards students' response may it be a wrong or right answer and teachers should be honest in showing a keen interest in whatever their students' reply may be.

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