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Teacher Questioning Strategies in Mathematical Classroom Discourse: A Case Study of Two Grade Eight Teachers in Tennessee, USA

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Abstract
Teacher questioning in mathematics is an important diagnostic tool for teaching as well as measuring the academic progression and comprehension of the learner. While teacher questioning enhances student learning and self-assessment of the teacher's lesson delivery effectiveness, if not presented properly can have negative impacts on the student learning process. Identifying "good" and/or "effective" questioning strategies is a major challenge to mathematics teachers. To increase teacher effectiveness and student success in mathematics, a self-assessment of teacher questioning techniques is essential. This study examines the questioning strategies used by two grade 8 teachers, selected at random, from twelve middle school teachers each handling quadratic mathematical modeling as one of their lessons in a project. The purpose of this study was to determine the questioning strategies used by the two teachers in their mathematical classroom discourse. Each class was videotaped over six-month period but only a section from each of the two selected classes, on quadratic modeling, was watched for about 45 minutes long for the purpose of this paper. A common theme "teacher questioning strategies" was the bases for analyzing the data. The strategies include: probing and follow-up, leading, check-listing and student-specific questioning. Findings from the study indicate that guiding teachers (pre-service and in-service) through an analysis of questions they ask and the responses they get from students during mathematical discourse, may enable them recognize both effective and ineffective questioning strategies in their mathematical classroom discourse. This study may help both pre-service and in-service teachers as well as teacher-researchers to be well aware of their questioning practices by reflecting on the questioning strategies they use in their own mathematical classroom discourse.
Keywords: probing and follow-up, scaffolding, checklisting strategy, leading questions, student-specific questioning

1. Introduction

The kind of knowledge students construct and communicate during a mathematics lesson may be dependent on teacher's questioning (Moyer & Milewicz, 2002). Teachers who can question correctly and effectively at various levels within the cognitive domain, such as knowledge, comprehension, analysis, synthesis, and evaluation (Bloom, 1956), are better able to discern the range of students' thinking. The use of good questioning, by teachers, may mean the difference between constraining thinking and encouraging new ideas, and between recalling trivial facts and constructing meaning (Kamii & Warrington, 1999).

Teachers' verbal behavior is a strong indicator of their total teaching behavior (Adams, 1994). Recent focus on the use of questioning in mathematical discourse supports the advancement of teacher's questioning strategies as a pivotal instructional process and tool in the student learning process (Wassermann, 1991). The need to develop appropriate questioning techniques is an important part of teaching and assessment for the mathematics student. Research studies in recent years have seen a surge of interest in the relationship between teacher questioning and students' knowledge levels; but student's level of understanding can be evaluated by teacher questioning strategies as an assessment tools.

When open-ended questions are used and there are many right answers, the learning environment becomes complex and less predictable as teachers attempt to interpret and understand students' responses. To do this effectively requires principled knowledge of mathematical concepts and understanding of how students think and reason mathematically (Lampert, 1986). Whereas experienced teachers have a repertoire of easily accessible strategies and pedagogical content knowledge, some teachers may have difficulty interpreting and responding to unexpected answers from children (Nilssen et al., 1995). Developing effective questioning strategies or skills could be an integral focus in mathematics in our contemporary classroom discourse.

National Council of Teachers of Mathematics states that "The teacher of mathematics should orchestrate discourse by posing questions and tasks that elicit, engage, and challenge each student thinking; listening carefully to students' ideas; asking students to clarify their ideas orally and in writing. A teacher's role is to be active in a different way from that in traditional classroom discourse. Instead of doing virtually all the talking, modeling, and explaining alone, teachers must encourage and expect students to do so. Teachers must do more listening and students more reasoning. For discourse to promote students learning teachers must orchestrate carefully" (NCTM, 1991, pp. 35-36).

1.1. Building Mathematical Classroom Discourse Using Effective Questioning

The use of alternative forms of assessment in mathematics such as combination of questioning and observing, has grown in popularity as result of the standards movement and other calls for reform in mathematics education (NCTM, 1991, 2000). Classroom teachers have used student interviews to guide and inform their own instruction in mathematics (Buschman, 2001). Mathematics teachers are encouraged to ask questions that help them to work together with their students and make sense of mathematics; to learn to reason mathematically; to learn to conjecture, invent, and solve quantitative problems; and to connect mathematics, its ideas and its applications (NCTM, 1991). Verbal interactions and performance-based assessments are seen as important parts of teaching and learning process in mathematics. Questioning and explaining have also been used as important means of diagnosing students' misconceptions and error patterns in mathematics (Ashlock, 2002). Teacher questioning and student explanation have the potential of ascertaining "the nature and extent of student's knowledge about a particular domain by identifying the relevant conceptions he or she holds and the perceived relationships among those conceptions" (Ashlock, 2002, p. 195). Teacher effective questioning and student's explanations in mathematical conversations rely on verbal communication as the primary means for eliciting this information from the participants.

1.2 Effective Questioning Strategies

Action research projects in classrooms have demonstrated that questioning students make teachers more aware of what the students know, and helps teachers to understand how students learn mathematics. Effective questioning may influence teacher's own instructional practices (Buschman, 2001). But developing effective questioning skills in mathematics classrooms requires shifting the practices and beliefs of the individuals engaged in those interactions. For this reason, some classroom teachers and university research are working collaboratively in action research projects to study how effective questioning techniques help teachers understand student thinking and guide classroom instruction, particularly in the mathematics classroom (Mewborn & Huberty, 1999). Although seemingly a basic activity that requires little expertise, effective questioning in mathematics mostly requires well-developed oral-questioning skills; the same skills teachers must use during classroom interactions. Based on synthesis of questioning research, Ralph (1999) proposes that basic oral-questioning skills should include preparing important questions ahead of time, delivering questions clearly and concisely, posing questions to students that stimulate thought, and giving students enough time to think about and prepare answers.

1.2.1 Probing and Follow-Up

Barnes (1976) contrasts teacher's use of 'reply' modes of answering student's questions with 'assess' modes. Based on this view, a teacher engages in a 'reply' mode of answering a students' question when the teacher takes the student's view seriously, and may wish to extend and/or modify it. In this approach, the teacher can question students based on incorrect responses, non-specific, or competent questioning of the student's view or answer (Moyer and Milewicz 2002). According to Barnes (1976), probing and follow-up questions strengthen the learner's confidence in active relationship. On the other hand, when a teacher 'assesses' what students say, he distances himself from their views, and allies himself with external standards which may implicitly devalue what the learner himself has constructed. Since teaching complement learning, the authors look at the students' role of both "presenting" and "sharing" and the corresponding teacher's role of "assessing" and "replying" (Barnes, 1976). Thus, probing and follow-up questions function both as a teacher's response to students' answers and an assessment of students' comprehension of the concepts learned.

1.2.2 Checklisting

A common behavior of teachers during questioning practices is "checklisting". When "checklisting", the teacher asks the questions, and may rely on the answer or how long the student(s) have stayed lingering (Calvert, 2001) rather than acknowledging the responses of the student. No matter what answer the student gives, the teacher simply moves on to the next item in mind. In essence, the teacher appears to be listening, not to the student's thinking, but for a response which then allows him or her to continue with the lesson. The result is often a fast-paced lesson, marked by lack of follow-up questions, and frequently accompanied by *verbal checkmarks*. The authors are using "checklisting" to indicate "no probing and follow-up" in the discourse at that point in time.

1.2.3 Checklisting Using Verbal Checkmarks

In addition to its pace, checklisting may be distinguished by the teacher's specific and repetitive use of verbal "checkmarks". These are one-or two-word verbalization, such as *okay*, *right*, *yeah*, *yep* or *good*, which indicates to the students that, somehow, it is no longer necessary to continue thinking about the question because the answer is "good enough" or accepted at that point in time (Calvert, 2001), and therefore, "check it off" and let's give way for another thing/question(s). More appropriately, a word or phrase becomes a verbal checkmark ending one task to begin another. On account of that *okay*, *right*, *yeah*, *yep* or g*ood* become the verbal checkmarks that end tasks and begin new ones. These also show how teachers who are checklisting may move rapidly from one question to the next, allowing little time for a complete response from the students. In this case, discourse might not be seen as effective communication system as defined by Cazden (1988). But checklisting could be seen as good *questioning clutches* (helping signs) to help teacher move on to the next item in mind or on the list for discussion.

However, when "okay", "right", and "good" are used to start statements in mathematics discourse, they might imply "get ready, we are moving on" - when the teacher is already satisfied with the previous discussions.

1.3 Scaffolding

To define and explain the metaphorical term "scaffold" Cazden (1988) used the following example:

> Imagine a picture of an adult holding the hand of a very young toddler with the caption. "Everyone needs a helping hand". Exactly as Resnick says, the child does what he or she can and the adult does the rest; the child's practice occurs in the context of full performance; and the adult's help is gradually withdrawn (from holding two hands to just one, then to offering only one figure, and then withdrawing that a few inches, and so on) as the child's competence grows (p.102).

Based on Cazden (1988) example, scaffolding questioning involves asking sequential step-wise targeted and transition questions that direct the learner from the initial acquisition to independent mastery of mathematical concept.

1.4 Leading questions/ Scaffolds

Leading questions are based on series of exchanges not just the introductory questions that need to be considered because they take into account the questions that may serve as scaffolds. In this paper, leading questions refer to both leading questions and scaffolds.

1.5 Student-Specific Questioning

Student-specific questioning was used by Anderson et al (2001) as an argument stratagem to describe how students invite their friends into discussions. The use, here, is rather from the teacher to students, inviting them into the classroom discourse. Students-specific questioning strategies are directed to specific students during classroom discussions to invite the students to contribute to discussion (Anderson et al, 2001). These strategies manage the participation of the students; and the structure includes "What do you think, [NAME of student]?" or "…, [NAME of student]" or "… [NAME of student], …?"

Effective questioning skills involves how questions and comments that are elicited and offered, and by which means the class comes to consensus. The content of mathematical discourse refers to the mathematical substance of the comments, questions, and responses that arise. Teaching commonly involves asking questions (form of reply and/or assess) in sequences that enable the teacher to control the direction and duration of the discussion (Bellack et al., 1966). They continued that teaching involves asking extended questions that enables the teacher not only to control the direction and duration of discussion but also maintaining a necessary degree of attention and order.

The study reported in Barnes (1976) indicates:

> There are two kinds of teaching: that which takes place in *expository* mode and that in *hypothetical* mode. In the former, the decisions concerning the mode and pace style of exposition are principally determined by the teacher as expositor; the student is the listener. The speaker has quite a different set of decisions to make; he has wide choice of activities; he is anticipating paragraph content while the listener is still intent upon the words; he is manipulating the content of the material by various transformations while the listener is quite unaware of these internal options. But in the hypothetical mode the teacher and the student are in more co-operative position with respect to what in linguistics would be called 'speaker's decision'. The student is not a bench-bound listener, but is taking a part in the formulation and at times may play the principal role in it. He will be aware of alternatives and may even have an 'as if' attitude towards these, and he may evaluate information as it comes (p.114).

1.6 Students' Role as "Presenting" and "Sharing"

Barnes (1976) discussed students' role in classroom communication as "presenting" and "sharing". According to Barnes, presenting establishes each participant as a unique and separate identity. Here, participants remain intact in self-boundary. Student's role as sharing, on the other hand, is one in which each participant abandons his facade and allows the other behind the seen. This implies collaboration and the willingness to take in the other's point of view. Regarding "replies" and assessing" Barnes has the following to say:

> The teacher's task as replies is the one in which he takes pupil's view seriously and may wish, even, to extend and modify it. This strengthens the learner's confidence in actively interpreting the subject-matter. Here the teacher and the learner are in collaborative relationship (p.111).

In the light of the explanation given by Barnes (1976), both the reply and assessment are essential part of teaching. Therefore, probing and follow-up, which may combine both reply and assess, is the authors' preference for use in this study (as indicated above).

1.7. Questioning Practices in the Classroom

Classroom questioning practice has been the focus of numerous education researchers for many years. Although it is widely assumed that classroom questioning promotes student thinking and learning, research in actual classrooms indicates that current practice falls far short. It is estimated that about 40 percent of classroom instructional time is spent asking questions, and approximately most questions are posed in a typical 50-minute class segment (Orletsky, 1997). Most of these questions are not well prepared and do not serve the purpose of prompting students to think. Orletsky (1997), stresses that questions should serve the purpose of having students share what they have been taught. Orletsky (1997), continues that studies have shown that lower-achieving students receive fewer opportunities to answer questions than other students. On the average, teachers wait less than 1 second for a student response. This is in contrast to the findings that when teachers wait 3 to 5 seconds after asking a question, students give longer, higher-level responses; answer with more certainty in their own responses; make more inferences; and ask more questions.

Orletsky (1997), explains that question-asking indicates that someone is curious, puzzled, and uncertain; it is a sign of being engaged in thinking about a topic. And, yet, very few students ask questions. Consistently, classroom research finds a large gap, with both students and teachers, between typical questioning and effective questioning that can affect student achievement. Thus, learning about questioning strategies for effective classroom discourse is a worthwhile sacrifice.

2. Significance of the Study

Guiding teachers through analysis of questions they ask and the responses they get from students can enable them to recognize both effective and ineffective questioning practices in their mathematics classroom discourse. This study will enable mathematics teachers to be well prepared in their questioning practices in mathematical classroom discourse; it may enable teachers question more effectively to prompt their students and engage them in critical thinking.

3. Purpose of the Study

The purpose of this study was, therefore: 1. to determine the questioning strategies used by the teachers investigating solutions for quadratic modeling, and 2. to analyze how they support students' learning, and categorize the strategies by reflecting on why teachers use particular questions strategies; and how such questions can be used as reflective tools to develop questioning strategies in their own mathematical classrooms discourse.

The objectives of the study:

1. To observe themes that may emerge outside the target task of the major project;
2. To observe how the emerging themes can help move learning forward

Research Questions

The research questions investigated were:

1. What themes are possible to be observed besides that for the big picture under investigation?
2. How can these observed themes be used to help move learning forward?

4. Limitations of the Study

1. The study is based on an analysis of a portion of a video recorded lectures over a period of six months from two mathematics classes taught by two teachers selected at random. Thus, the results may not be generalizable to all mathematics classes; but the self-reflection approach is usable to mathematics classes and any other quantitative classes, to improve teaching and increase student retention.
2. The video tape is not available publicly for ethical reasons.

5. Methodology

Twelve middle school class teachers were purposively selected, from among 400, for teaching quadratic modeling in their lessons; and videotaped over six-month period, to give a clear observation of general interaction of mathematical discourse in the classroom purposely for teacher education. But for the purpose of this paper, the video was analyzed by the research team to observe student-teacher interactions in terms of teacher questioning practices only and students' responses from two teachers randomly selected from among the twelve teachers. Joshua and Kola (pseudonyms) were among the twelve randomly selected teachers. The theme "teacher questioning strategies" was used to analyze the transcribed data of the two video tapes in their (the two teachers') mathematical classroom discourse lessons, as indicated above; the theme was what the research team agreed upon to use for analyzing the tapes. The tapes were qualitatively analyzed; and the qualitative analysis of the transcribed video-tapes form the bases for the data for the study. Like the teachers, pseudonyms were used for the students-participants during the classroom interactions.

5.1 Data Analysis

As indicated above, this is a qualitative study and the qualitative analysis was done as follows: After listening to the two video tapes, the tapes were transcribed and analyzed as follows:

a. Twelve classes labeled 1, 2, 3… 12 on 4 cm x 4 cm pieces of paper were purposively selected from among 400 teachers. The teachers were purposively selected, from the other teachers, for they taught quadratic modeling in Grade 8 during the research period. The twelve 4 cm x 4 cm pieces of paper were scrambled and put into a box to enable shuffling and random selection.
b. The scrambled papers were shuffled with rigorous shaking of the box which contains them.
c. With eyes closed two pieces of the scrambled papers were selected, one at a time.
d. After the first piece was selected, the number on the 4 cm x 4 cm paper was observed and NOT put back in the box for the second selection
e. After two classes were randomly selected, as indicated above, after the second trial, the video tapes containing these two classes were selected from among the twelve. Each video tape has the same set of lessons taught by each of the twelve teachers - quadratic modeling.
f. After selecting the two classes (classes for Joshua and Kola), the researchers first watched the two selected videos to come out with a common theme all of them will agree upon; then watched them again, twice, before they started to record their observation;
g. The transcripts (transcribed materials) were read and re-read;
h. All the questions and their corresponding answers were numbered for each lesson;
i. Themes arising out of the data were written down;
j. Now the transcripts were slowly read and the numerals pertaining to any particular theme were written under each theme;
k. The process explained in j (above) was used for each set of transcript;
l. After reading and distributing the numbers to each respective theme, the computer was used to select the items to their respective themes;
m. After the process i (above), the themes were carefully read and some were merged and the transcribed items that appeared more than once were put under appropriate themes.

6. Findings and Discussions

Several questioning patterns emerged as teachers in the videotape were seen as authorities in authority (Russell, 1983) and control of class discussions that seemed indicative of differences in questioning practices. Questioning strategies were categorized as:

- *Probing and follow-up*, where different types of questioning are used to further investigate students' answers; and these were used to perform the functions of both "reply" and "assess" which include questioning the correct responses, and or questioning the incorrect responses of students;
- *Leading questions* that intend to direct students' responses, where leading questions here also refer to scaffolds;
- *Checklisting*, where the teachers proceeded from one question to the next with little regard for the students' responses, which include questions with "verbal checkmarks";
- *Student-specific questioning*, which teachers used to gain floor for students.

6.1 Probing and follow-up Questioning Forms

The use of probing and follow-up questions during mathematical discourse demonstrates the teacher's greater attention to the student's thinking. While the checklister (third strategy, above) often asks no follow-up questions, the probing teacher responds to the student's answer(s) with another relevant question(s) in an attempt to get the student to explain his or her answer or think about it further. Rather than signaling the end of the task upon giving the right answer, especially in (3), this strategy communicates to the child that the answer is still open for discussion. Yet not all probing and follow-up questions adequately or appropriately assess what the student is thinking. Follow-up and probing questioning, in mathematical classroom discourse, categorized here, include questioning both correct and incorrect responses, and these questioning forms specifically and consistently probe the students' answers.

6.1.1 Probing Correct and Incorrect Students' Responses

There are several instances where teachers only question students when they give an incorrect response; many do not follow-up when a child's response was correct. This practice works with the assumption that because students produce the correct answers, the students understand the concepts. But a student could voice out correct answer from friends without explicitly understanding the meaning. In the following interaction from the video tape, the teachers (Joshua and Kola) probe both the correct and incorrect responses from students.

Excerpt 1 (a): Solving Quadratic Equations of the form $ax^2+bx+c = 0$, where a, b, and c are integers; and a=1, c=0, where "…" refers to a set of question(s).

> …
> *Joshua: What are they? Alicia, Jennifer, Robert have an answer, Carl, Jaylen, how? Jaylen, what are the x-intercept?*
> *Jaylen: Zero and negative three.*
> *Joshua: How do you get your answers?*
> …

Excerpt 1 (b): Solving Quadratic Equations of the form $ax^2+bx+c = 0$, where a, b, and c are integers; and a=1, c=0. (Without using the Graphic Calculator, where "…" refers to a set of question(s))

> …
> *Joshua: How could you do that here? You do an x-squared times zero?*
> *Sandy: In factored form, um, in the parenthesis, x times zero, or x plus 0 is zero and then x plus negative 3 equals zero. So you need to use the negative or positive of that number.*
> *Joshua: This is multiplication problem, isn't it? Isn't any number times zero, zero?*
> …

Questioning the correct and incorrect responses of students is where the teacher identifies himself or herself as authority in authority, as indicated above. In excerpt 1 (a), Jaylen got the right answers (x=0, x=-3), but the teacher, Joshua, wanted to find out if Jaylen could express his knowledge by explaining his answer; so he asked Jaylen "How do you get your answer? In Excerpt 1 (b), however, the teacher questioned unclear response from Sandy. She first said "In factored form, to explain the method. Then she tried to explain how she did it. But her expression "x times zero, or x plus 0 is zero and then x plus negative 3 equals zero. So you need to use the negative or positive of that number" is somehow okay, but not clear at all; her work itself needs some explanation; and it was the teacher's burden to give a good probe to bring about critical thinking and not to tell the answer. But was it coming forth? In the video Sandy wrote "x^2 (x -3) =0" on her paper; and trying to explain that x = 0 and (x -3) = 0 [for solving the equation $(x^2 – 3x) = 0$, using factorization]. Obviously, her factor "x^2" should have been just "x" (not x^2). The teacher used probing and follow-up (questioning scaffolding), carefully to bring Sandy back to her own history of mathematical experiences saying "This is a multiplication problem, isn't it? Isn't any number times zero, zero? …"

In Excerpt 1(c), below, are both correct and wrong responses from the students but the teacher probed only the one with the incorrect answer.

Excerpt 1(C): Karla's Transcript: Exploring Quadratic of the Form $ax^2+bx+c = 0$, where a, b, and c are integers; and a=-1, c=0, (see below, where "…" refers to set of question(s)).

> …
> *Charity: Upside down U*
> *Barbie: Quadratic?*
> *Charity: Yeah*
> *[Others talking inaudibly]*
> *Mark: A hill thing*
> *Kola: How do you know it's gonna be a hill thing?*
> …

The curve "$-x^2+bx$" is a quadratic expression which is concave down; starting from a positive slope, from the left, get to the highest point and then becomes negatively sloped to the right. In this case Charity's U is incorrect, but "upside down U" is rather correct for it implies that Charity was rather referring to "inverted U" not U itself. The teacher should have questioned her but he neglected her and questioned Mark's "A hill thing" which was rather correct; unless he was trying to explain what Charity means and not necessary to the right explanation. Even though Barbie asked Charity whether she was referring to quadratic, which actually could be either a U shaped or inverted U, the teacher used her authority as the one in authority (Russell, 1983) to question Mark; and she started with "How do you know it's gonna be a hill thing?" The teacher probably asked him the question to bring about knowing mathematics as "taken-as-shared" (Cobb, 1992), which is hypothetical in mode (of teaching). Mathematics taken-as-shared usually safes the face of the presenter and avert emotional predisposition they might have gone through if they were to defend themselves for their right or wrong answers given, especially if they would not be able to satisfactorily explain their own work.

6.2 Leading Questions

Many teachers use questioning strategies that are *leading forms* and in essence attempt to guide and prompt the students to the correct answer without explicitly telling the answers. Excerpt 2 (a) and (b) involves examples of leading questions the teachers used (where "…" refers to set of question(s)).

Excerpt 2 (a): Solving quadratic equations

…

Joshua: Where are the x-intercepts for this? So, in other words if I set this equation to zero … if you want to put 0 over on this side- because it's a y, it doesn't make any difference [referring to writing the equation either as y = the equation or the equation = y –pointing out that the order in which the student writes it doesn't affect the equation and the answers]. What are your x-intercepts? There might be one or two or there might be no intercept. Use your graphing calculators. Where are the x-intercepts? In other words, where is the quadratic going to cross the x-axis?

Alicia: It's in the book.

Joshua: Pardon me?

Robert: 0 and negative 5.

…

Students seldom fully understand mathematical questions when asked by their teachers orally or written on the board. Leading questions are used to help students to meaningfully understand problems on the table for discussion. Joshua, in Excerpt 2 (a), was reviewing quadratic equations with his students [It appears they had already discussed it in class]. Alice's statement "It's in the book" may suggest that it is given in the book when they discussed it (maybe in the past lesson) and thus it's obvious; so Alice might be referring the teacher to them, in the book, instead of saying what they are.

Excerpt 2 (b): Solving quadratic equations symbolically- writing expanded form in factored form

…

Joshua: Okay, Symbolic. Let's take a look at Problem 4.4. If you look on page 58, we gonna look at another quadratic. It asks you to look at x squared plus 3x is in expanded form. How would you write that in factored form [put up overhead screen]? In fact everyone should be able to do that by now …

Joshua: If I was to draw a rectangle with the area "x squared plus 3x", how can I do it, Jennifer [I'm referring back to the area model you used to factor quadratics in the frogs unit]?

…

Like excerpt 2 (a), excerpt 2 (b) was when Joshua was leading students into solving quadratic equations symbolically using factorization. From observation of the videotape Joshua asked a series of leading questions before he finally invited Jennifer into the discussion. Leading questions here could be "scaffolds" (as indicated above) to help student gradually to understand the mathematical concepts and thus be able to work on their own.

6.3 Checklisting Strategy

Checklisting questions are characterized by the degree to which they precludes the student from expanding on their answers. When the teacher asks no follow-ups questions, he or she risks obtaining no information about the student's mathematical thinking by not specifically inviting it. The following are examples from the two teachers in the video, Joshua and Kola, (see below, where "…" refers to set of question(s) as usual).

Excerpt 3 (a) Joshua's transcript: Solving quadratic equations

…

Jaylen: The x-intercept are zero and negative three

Joshua: Okay, agreed? [Referring to whole class]

Class: Yes/yep/agreed [class responded]

Joshua: Okay. Now … [Joshua moves on]

…

After Jaylen answered "The x-intercept is zero and negative three" Joshua should have followed up with further questions about how Jaylen got them but this time he didn't, probably, they have had enough discussion on the subject matter; so he just asked the class if they agree; and they all gave an affirmative answers like *yep, yes, and agreed*. Then he moved on. Joshua's "okay" might indicate that it is enough to move on to the next item. At this point students who did not understand the concept may have to contact the teacher at a stipulated time or consult friends for further explanation.

Excerpt 3 (b) Kola's transcript: Exploring quadratic equation of the form $ax^2+bx+c = 0$*, where a, b, and c are integers; and* $a=-1$*,* $c=0$*,* (see below, where "…" refers to set of question(s)).

…

Johnson: It crosses at zero, zero and…

Mark: Five, zero

Charity: It crosses at zero

Kevin: The table, look at the table
Kola: Okay ...
…

It is not clear who Kola's "Okay" refers to. She should have paid attention to Johnson's "It crosses at zero, zero and…"for we expect only two answers for the equation $-x^2+bx = 0$; and Charity's "It crosses at zero" might need some explanation why the solution is just one answer. Kola's "Okay" may suggest that all answers are "good enough" to continue to the next item for the day. As indicated above, students who do not understand the concept, in the class, may have to contact the teacher at a stipulated time or consult friends for further explanation.

6.4 Student-Specific Questioning

Students-specific questioning strategies are directed to specific students during classroom discussions to invite them to contribute to discussion (Anderson et al, 2001). These strategies manage the participation of the students; and the structure is "What do you think, [NAME of student]?" or "…, [NAME of student]...?" or "…, [NAME of student]…?" (see excerpt 4, below, where "…" refers to set of question(s)).

Excerpt 4: Solving quadratic equations- without using the Graphing Calculator

…
Joshua: What are you looking at, Chuck, the expanded form or the factored form?
Chuck: I looked at the expanded form
Massi: I have no idea
Joshua: For the expanded form? [This question was directed at Chuck, after Massi's interruption. Chuck nods "yes"]
Joshua: What do you think, Mindy?
Mindy: [inaudible] think about what number you take times to get to zero [inaudible] whatever the three times what equals zero.
…

The purpose of this students-specific questioning strategy is to get others into the discussion to consider the situation from different perspective (Anderson, 2001). From the above discussion, the teacher wanted to know which approach students were considering to solve the quadratic equation without using the calculator. The teacher's asking of student(s) to join a discussion is an indication of openness to alternate ideas, which is often considered to be the hallmark of classroom discourse. Also questioning indicates that someone is curious, puzzled, and uncertain (Orletsky, 1997). By observing the two teachers' questioning strategies in their questioning practices, it was evident that the probing and follow-up, the leading as well as the checklisting and the student-specific questioning strategies portray mathematics classroom discourse as a system that moves learning forward. From the findings above, Joshua and Kola brought a variety of questioning strategies to their mathematical classrooms discourse to bring forth a world of significance to their students (Calvert, 2001). Their use of appropriate questioning strategies is important skill to develop for such mathematics classroom discourse: The teachers used the follow-up questions, particularly, to question students for both correct and incorrect responses; they used the follow-up strategies to specifically focus on students' thinking and to probe students for their right or wrong answers; the probing and follow-up as well as the student-specific strategies were used to ascertain the nature and extent of students' knowledge about the concept on the table for discussion - in this case "factoring quadratic equations", "the roots of quadratic equations", and "solving with and or without the use of the calculator". Furthermore, the questioning strategies helped to evaluate students' understanding of solving quadratic equations with or without the graphing calculator.

Teachers usually attempt to direct students, when questioning, in their mathematical discourse rather than telling them the answers. In many instances they use leading questions that direct the students' responses or provide hints about where they are going about the procedures, the answers or sometimes simply abandon the strategy of questioning and attempt to teach the concepts by giving further explanations.

Verbalization such as *okay*, *right*, *yeah*, *yep* or *good*, might indicate to the students that, somehow, it was no longer necessary to continue thinking about the questions because the answers were "good enough" and therefore, have to consider moving on with other things. On account of that *okay*, *right*, *yeah*, *yep or good* become the verbal checkmarks or more appropriately *verbal clutches* that ended one task and began another.

The student-specific strategies, in the form "What do you think, then [NAME of a student]?" or "…, then [NAME of a student]?" or "…, then [NAME of a student], then …?" appeared only a few times in the video. However, they appear to be useful ways of managing participation of students, especially those whose hands were already up and were ready to contribute or even those who were "anti-social" and did not want to talk in class discussions. The strategy makes every student ready to participate in discussions for the teacher may invite any student all to participate.

The teachers' interaction in mathematics discourse relies heavily on verbal language to carry information between the teacher and the students and among the students for knowledge construction. This promotes student *collaboration* (where meaning is negotiated through explanation, clarification, elaboration, further questioning, evaluation, justification and arguments); it also promotes *consensus* (where accommodation to existing schemas occurs that enriches and expands existing constructs), and finally *sharing* (where collaboration and consensus occur again and again) to move learning forward (Etchberger & Shaw, 1992).

7. Conclusion

In conclusion, this paper brings to focus the importance of the awareness of the questioning strategies to facilitate effective interaction in mathematical classroom discourse. Whatever be the grade level, mathematics teachers must use their authority (Russell, 1983) to facilitate learning of mathematics concepts by summarize usefulness of each strategy here, if possible. To realize this, teachers are required to be aware of these questioning strategies to equip them to effectively handle mathematics classroom discourse.

8. Educational Implications

The findings may provide an important contribution to the literature on questioning techniques to be used in teacher education programs and as professional development item for in-service teachers. The findings may serve as a framework to support all levels of questioning categories in Bloom's taxonomy (Bloom, 1956): Identifying questioning patterns, in questioning practices, may allow educators to have a shared discussion about the kinds of questions to expect in a mathematical classroom discourse.

Teacher-Researchers could document the frequency with which they use "probing and follow-up", "leading", "checklisting", and "student-specific" questioning strategies to enhance teaching and learning. The strategies could be used during self-analysis of teacher's own questioning practices.

The techniques used in the analysis involved in this study can be applicable to any discipline to increase student engagement, enthusiasm, interest, and collaboration in class. Addressing these factors at middle or high schools is also likely to increase students' motivation and interest to pursue Science, Technology, Engineering, and Mathematics in postsecondary education, where success is strongly dependent on the knowledge and interest in analytical skills.

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