

PROMOTING STUDENT QUESTIONS IN MATHEMATICS CLASSROOMS

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Question asking is an important part of the learning process. One of our goals as educators is to encourage students to ask questions that focus on developing conceptual knowledge. To do this, we first need to better understand the factors involved in student question asking. This study looks in depth at one high school mathematics teacher who promotes rich, mathematical question asking among her students. She does this by creating a safe learning environment, shifting responsibility to learn onto her students, by modeling good question asking, and through explicitly valuing sense-making. This study hopes to help teachers and educators think about how to promote more student questions in mathematics classrooms.

Keywords: Classroom Discourse, High School Education

Objectives

Question asking is an important part of the learning process. The NCTM *Principles and Standards for School Mathematics* (2000) states that “students gain insights into their thinking when they formulate a question about something that is puzzling to them.” The process of asking a question allows the student to verbalize her current understanding of a topic and connect that knowledge with other ideas (Marbach-Ad & Sokolove, 2000). Stipek and colleagues (1998) found that when a student asks a question, she is motivated to learn. Through student questions, teachers can determine how students are thinking about the content of instruction, giving them an opportunity to tune instruction to the intellectual needs of their students (Rop, 2002). Teachers identify student question asking as critical to successful participation in the educational setting (Salend & Lutz, 1984). Clearly, one of our goals as educators is to encourage students to be inquisitive and ask questions. To do this, we first need to better understand the factors involved in student question asking.

There are multiple studies on student question asking in science education (see Marbach-Ad & Sokolove, 2000; Kelling, Polacek, & Ingram, 2009; Rop, 2002 and 2003 for examples) and in English Language Arts instruction (see Rosenshine, Meister, & Chapman, 1996 for a review), and there are studies that look at *teacher* questioning patterns in mathematics classrooms (Boaler & Brodie, 2004) but few studies specifically address *student* question asking in mathematics classrooms. This study attempts to understand what questions students are asking in their mathematics classroom as well as how mathematics teachers can promote question asking among students.

Webb et al. (2009) showed that teachers’ instructional practices are related to the students’ classroom dialogue. They write, “It is imperative not only to analyze the dialogue among students, but also to examine student participation in relation to teacher participation and the context of the classroom.” Hufferd-Ackles et al. (2004) showed that math talk among students changes as teachers change their teaching. Similarly, my study attempts to understand how a teacher’s practice affects the student questioning in her classroom. Specifically, I ask how does one high school mathematics teacher promote question asking among her students?

Methods

A Case Study Approach

In the spirit of Milo Small (2009), I choose a unique teacher for my case study, rather than attempting to find an average teacher or a representative case. According to Small, unique cases are especially interesting because they provide ways of developing or extending theories. For this study, I choose to analyze Susan Santiago's¹ teaching practice. Ms. Santiago is a National Board Certified Teacher, a Presidential Awardee for Excellence in Mathematics Teaching, and a member of the state board of the California Mathematics Council. At the time of the videotaping, Ms. Santiago had been teaching high school mathematics for 22 years. In addition to her excellent reputation and vitae, I choose Ms. Santiago because of her curriculum: the *Integrated Mathematics Program* (IMP). This curriculum encourages students "to experiment, investigate, ask questions, make and test conjectures, reflect, and accurately communicate their ideas and conclusions [emphasis mine]" (Webb, 2003). Most U.S. high school mathematics teachers use a more "traditional" curriculum that may or may not promote student question asking. Because the IMP curriculum was specifically designed to encourage student question asking, Ms. Santiago's classroom is an ideal place for my research.

Data Sources

One way of capturing the many details of teaching is through videotaping instruction. Video observations allow researchers to go back and observe a class over and over again, a process that helps researchers become more deeply aware of what is going on each time through the videos. This "progressive refinement of hypotheses" (Derry, 2010) enables researchers to modify, hone, and solidify ideas each time through the data. Engle (2007) wrote that going through multiple iterations of hypothesis generation and evaluation leads to greater robustness of findings and increases the likelihood that findings will be replicated in other contexts.

A research team videotaped Susan Santiago's mathematics Algebra and Pre-Calculus classes throughout the 2000-2001 school year. One camera stood in the back of the room and Ms. Santiago wore a microphone throughout the videotaping. Of the approximately 50 video tapes available, I transcribed fourteen lessons where there was full-class instruction and discussion (vs. small group work). I transcribed six videos from the beginning of the school year in order to see how norms around student question asking were established. Then I chose eight more videos so that they would be well spaced throughout the year.

Student Question Categories

While question asking is critical to the learning process, not all questions are of equal learning value. There are students who use questions to disrupt the learning process when they try to show off or derail a lesson. There are students who ask questions for procedural information or just to get the right answer. Then, there are students who ask questions as they seek conceptual clarification and understanding. To begin to study the variety of questions Ms. Santiago's students ask, I used a student question categorization developed by Good (1987) and his colleagues (see Table 1). Good's categories are meant to capture the wide range of questions students ask as well as be a tool that researchers can use to measure the quantity and quality of student questions in a classroom. I include an example of each type of student question in the table. I also added a category for questions about technology.

Table 1: Coding Schema for Student Questions in Ms. Santiago's Mathematics Classes

Type of Question	Example from transcripts
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¹ Pseudonym

<i>Explanation:</i> This type of question requests meaning or reasons that help in understanding a mathematical concept, idea, task, or procedure.	Example: “Why are you finding the inverse?”
<i>Information:</i> This type of question seeks specific, factual, academic information.	Example: “Are all the lines called curves on a graph?”
<i>Clarification:</i> This type of question requests clarification of information, procedures, comments, or tasks provided by the teacher or others.	Example: “I don’t understand that last part. Why do we need the 225?”
<i>Confirmation:</i> This type of question seeks confirmation of a completed student response, procedure, or task.	Example: “Don’t we need two measures to find the minor arc and don’t we only have one?”
<i>Procedural:</i> This type of question concerns classroom procedures. This category does not identify questions about procedural mathematics. Rather, this category identifies questions that have to do with the way the class is organized, performance measures, grading procedures, etc.	Example: “Would you put this kind on the test?”
<i>Diversion:</i> This type of question diverts the teacher’s or others’ attention from the task at hand.	Examples: “Do colleges prefer cursive or printing?” or “Can I go to the bathroom please?”
<i>Attention:</i> This type of question draws attention to the question asker.	Examples: “Do you want me to try to explain?” or “Can I blow on [the dice]?”
<i>Technology:</i> This type of question requests help in using technology to solve the problem at hand.	Example: “How do you type in [to calculator] the fourth root?”
<i>On-task curiosity:</i> This type of question displays curiosity tangential to the immediate task.	Examples: “Are you going to do one with like 36 sides?” or “I have a question about when I would use a t-table, like at a job.”
<i>Unknown:</i> This code was used when a student question was inaudible or undecipherable from the videotape.	

Coding

For each of these videos, I went through two levels of transcription. The first level’s purpose was to transcribe as much of the dialogue as possible and to timestamp and highlight all student questions that occurred during whole class discussions. The second level was to more carefully capture the exact wording of each student question as well as the dialogue approximately one minute before and one minute after each question. Next, I counted and categorized all student questions from the transcripts (see Figure 1 for results). A fellow researcher counted and categorized student questions in two of the transcripts and our reliability was 71%. Next, I open coded (Glaser, 1978) each line of the transcripts. Soon I began to see patterns and themes and began to engage in meaning making (Geertz, 1973) of the data. As I went back and read through the transcripts again and again, I revised and solidified my thinking about what components of Ms. Santiago’s teaching promote question asking among her students. As these hypotheses developed, I continually asked myself whether my inferences were logical (Small, 2009). All this led me to hypothesize four important components of Ms. Santiago’s classroom that encourage

students to comfortably participate in inquisitive mathematical communication. These components are 1) a safe classroom environment, 2) a shift in authority from teacher to student, 3) teacher modeling of question asking, and 4) explicit value of sense-making in the classroom.

Results

The following table shows the types and quantity of student questions in Ms. Santiago's mathematics classroom. The sheer number of student questions is remarkable. Each transcribed lesson is only 50 minutes long, and thus Ms. Santiago's students ask questions, on average, every two minutes throughout instruction. It is also interesting to note that the Pre-Calculus students asked more *Explanation*, *Information*, and *Clarification* questions (70% vs. 43%), indicating that they were more engaged in the mathematical material at hand than the Algebra students. The Algebra students asked more confirmation questions (10% vs. 5%), indicating that they were more interested in the answer (vs. process of getting there). The Algebra students also asked more procedural questions (16% vs. 9%), an indication that they were more interested in classroom organization, grading procedures, upcoming tests, etc. than the more advanced students. The Algebra students asked more diversion questions (13% vs. 3%), indicating that they were more easily distracted than the Pre-Calculus group, and they also asked more attention questions (6% vs. 1%) which, when looking closely at the transcripts, indicates an eagerness to participate in learning activities. There were also important qualitative differences between the IMP1 and IMP4 classes. For example, in the Algebra class, confirmation questions often indicated that the student asking the question *assumed he was wrong* and sought verification of this. Two examples of such questions are: "It's not nine, is it?" and "I'm just wondering because you told me we didn't have to go up past six sides and... I'm just wondering if we did it wrong." In the Pre-Calculus class, however, the student asking the confirmation question often *assumed he was right* and sought verification of this. Two examples of such questions are: "Wouldn't 7.74 minus 10.88 be the period?" and "So it's just 96 divided by 2?"

Question Category	Algebra Average	Percentage	Pre-Calculus Average	Percentage
Explanation	4.8	18%	5.9	22%
Information	2	8%	3.6	13%
Clarification	4.5	17%	9.5	35%
Confirmation	2.5	10%	1.4	5%
Procedural	4.3	16%	2.4	9%
Diversion	3.3	13%	0.8	3%
Technology	0.3	1%	1.4	5%
Attention	1.5	6%	0.3	1%
On-task curiosity	1.3	5%	1.1	4%
Unknown	1.8	7%	0.8	3%
Total	26	100%	27.2	100%

Figure 1: Student Questions in Ms. Santiago's Mathematics Classes

Counting and categorizing Ms. Santiago's students' questions helped me understand *what* kinds of questions her students were asking, but I was also interested in *how* Ms. Santiago is able to promote question asking among her students. As mentioned in the Methods section, I found

four main components of Ms. Santiago's instruction that seemed to promote student questions asking. First, I explain each component and give examples from the transcripts. Next, I provide Figure 2 that contains the breakdown of the four components in Ms. Santiago's classroom.

Safe Classroom Environment

In order to learn something new, a student must enter unknown intellectual terrain, and it is unrealistic to expect that the student will immediately understand a new concept or idea. Throughout her instruction, Ms. Santiago tries to make her students feel safe as they engage in the often messy and unpredictable process of learning. In fact, Ms. Santiago makes reference to the importance of making mistakes, of being comfortable with intellectual ambiguity, and the value of asking questions on average 4.9 times per hour. When a student is up at the board presenting her solution to a problem, another student asks, "Wouldn't that not work because it's seven feet above the fence?" Ms. Santiago responds by asking the class, "What do we think?" The student at the board says, "I don't know. That's what I did." Then Ms. Santiago says, "Her answer is coming out close to the correct answer. Why do you think that is?" No one answers, so then Ms. Santiago says the following:

Okay, you know what, my philosophy is. She's got a lot of good math going on here and he's got an excellent question. So I love it when people go up and present. She's very close to the right answer and we're able to ask ourselves is it right and what's going on here, so very good job. Did anyone do it a different way?

This statement promotes a classroom culture where it is safe to make mistakes, not know things, and ask questions. After another student has been at the board and has explained her solution and answered other students' questions about her solution, Ms. Santiago says, "so that was a very nice job...some people go up and do some of the problems and some people ask questions and that is what we want to do." This safe learning environment allows students to publicly convey their only partially developed understanding without suffering negative consequences.

Shift in Authority

Another way that Ms. Santiago promotes student question asking in her classroom is through a shift in authority from herself to her students. Throughout her classes, Ms. Santiago conveys to her students that it is their responsibility to internalize mathematical concepts. Instead of standing in front of the classroom and lecturing, Ms. Santiago guides and supports her students as they develop the confidence to learn for themselves. On average, Ms. Santiago mentions something of this sort 3 times per hour. The following are two examples from the transcripts of how Ms. Santiago shifts the authority to her students to learn and make sense of the mathematics.

Ms. Santiago: So now that this group is finished, we need to go over minimum and maximum.

Student: Can I do it?

Ms. Santiago: Okay, and *the rest of you need to decide* if the numbers are right or wrong.

Student: What do we work up to?

Ms. Santiago: Well *you decide*. You know the game.

This shift in authority encourages student questions because as students become more active in their own learning, they will have questions—the very act of trying to learn something new means that there will be things a student does not understand, and whether stated aloud or not, questions form in the students' minds.

Modeling of Good Questions

Another way Ms. Santiago promotes question asking among her students is through asking good questions herself. On average, Ms. Santiago asks 57 questions per hour. Her questions not only indicate what kind of thinking and learning she values, but also model what kinds of

questions she expects from her students. Table 2 shows a few of the 775 questions I listened to Ms. Santiago ask while doing this research.

Table 2: Examples of Ms. Santiago's Questions

<ul style="list-style-type: none"> • How would we know? What will it look like? • Okay what am I trying to find? • Why isn't that negative? • Why do I know this is constant acceleration? Can you prove to me that you are going faster than 25 miles per hour? • How do you know that? Who has something to add to the discussion? • So how am I going to write this mathematically? Is there another way she could have written the answer instead of $y=n$ times n? • Okay, what do you think is the purpose of the worksheet? Earlier in the year you heard me say this was a bad bad bad mistake. (She circles the answer.) Why is that?

These questions indicate that while Ms. Santiago does care about mathematical correctness, she values mathematical understanding even more. Ms. Santiago's students are exposed to rich mathematical question asking, and through this, they learn to ask good questions themselves.

Sense-making Valued

Yet another way Ms. Santiago promotes student question asking in her classroom is through valuing sense-making. On average, Ms. Santiago refers to the importance of making sense of the mathematics 4.25 times per hour. This frequency makes her intention clear: she does not want her students to simply memorize formulas or procedures. Instead, she wants them to internalize and make sense of the mathematics. The following are some quotes from her classes that show how she expresses this expectation to her students:

“This particular problem you'll find again and again and again. So you *if you don't understand how to do it, it's really important that you ask questions* ...okay, very nice job”

Later in the same class, Ms. Santiago uses a visual representation of the mathematics and says, I'm trying to show you where it comes from in the picture. Do you see where this comes from the picture? *I want to show you how things are coming from the picture, not just give you a formula to plug in.* Do you see how it relates to this picture?

Ms. Santiago wants her students to understand mathematics. It is not enough for her students to blindly use formulas. She teaches them to ask themselves whether or not things make sense.

The following table shows the frequency of these four components in Ms. Santiago's classrooms:

Incident	Algebra Average (times per hour)	Pre-Calculus Average (times per hour)	Total Average (times per hour)
Safe-learning environment	6	3.75	4.88
Shift in authority	3.5	2.5	3
Ms. Santiago's questions	63.5	50.5	57
Sense-making emphasized	4.25	4.25	4.25

Figure 2: Breakdown of the Four Components in Ms. Santiago's Classrooms

Discussion and Significance

Traditionally, the school teacher has been seen as the source of knowledge and the one responsible to ensure that her students actually learn. In science and ELA classes, it has been shown that if a teacher is able to create a shift that places the source of knowledge in the subject itself and places the responsibility to learn and understand onto individual students, then students ask more questions as well as a wider variety of questions (Chin & Brown, 2002; Oyler, 1999). Ms. Santiago's classroom shows us that this is true in mathematics classrooms as well.

Shifting responsibility to learn onto students pushes them to engage in sense-making, a process that cultivates questions. In order for students to actually vocalize these questions, however, they must feel safe in the classroom and must know that it is productive to ask questions. Pearson and West (1991) found that students often don't ask questions because they fear a negative reaction from their teacher. Ashcroft (2002) found that how a teacher responds to a student question can either heighten or allay students' math anxiety. In Ms. Santiago's classroom, she values student questions and carefully and thoughtfully answers them. This safe learning environment makes it easier for students to reveal misconceptions and gaps in their understanding.

We see that shifting authority to learn onto students' shoulders compels them to engage in sense-making, a process that generates questions, which are vocalized if a safe learning environment exists. Ms. Santiago pushes this a step further by literally showing her students *how* to ask good questions. Her students are continually bombarded with her mathematical questions, and her students respond to this environment by asking many questions of their own.

Some teachers attempt to tightly control everything that happens in their classrooms. They carefully plan their lessons and rarely deviate off course. There is minimal room for autonomous learning in these classrooms (Greeno, 1991). Because students are inured to transmission style teaching and learning, they are not likely to ask as many questions in class because they are not likely to see themselves as inquisitive participants in the learning experience. Unfortunately, this type of teaching is particularly prevalent in U.S. mathematics classrooms. The case of Ms. Santiago, however, shows different possibilities for promoting participation and engagement in the classroom that will likely lead to more conceptual student questions.

Limitations

This study reports on the experience of only one teacher, and future studies are needed to ascertain whether the four components proposed in this study lead to increased question-asking in other classrooms with different teachers and students. A larger study could look at a diverse sample of teachers and classrooms to determine if there are reliable associations between the four components and student question asking. Also, we need a categorization for student questions designed specifically for mathematics classrooms. While Good's (1987) categorization provided a place to start looking at quantity and quality of student questions, it became very clear while I was doing this research that a more specific categorization is needed.

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