NOT ALL QUESTIONS ARE ALIKE: CREATING A CATEGORIZATION FOR STUDENT QUESTIONS IN MATHEMATICS LESSONS

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Students ask a variety of questions during mathematics lessons. Some questions focus on procedures or formal notation, while others focus on ideas, connections, or representations. Student questions are important as they provide vastly different learning opportunities for students. In order to support teachers as they help students learn to ask productive questions in mathematics lessons, we need to first understand the types of questions students ask. This paper describes the process of creating a categorization for student questions in middle and high school mathematics classrooms.

Keywords: Classroom Discourse, Middle School Education, High School Education

Question asking is an important part of the learning process. The National Council of Teachers of Mathematics (NCTM) *Principles and Standards for School Mathematics* (2000) states that “students gain insight into their thinking when they formulate a question about something that is puzzling to them.” Question asking affords students opportunities to extend their own understanding of lessons as well as to raise personal concerns about topics discussed in class (Daly, Kreier, & Roghaar, 1994). Posing questions not only shapes students’ thinking, but also exposes it, which provides opportunities for teachers to learn more about their students’ understanding (Marbach-Ad and Sokolove, 2000). Students who ask questions retain material better than those who do not (Marbach-Ad & Sokolove, 2000), and asking questions in mathematics lessons is linked with motivation (Stipek, Salmon, Givven, Kazemi, Saxe, & MacGyvers, 1998).

While it is clearly a useful activity for students to ask questions in classrooms, students often refrain from asking questions because they fear a negative reaction from their teacher (Pearson & West, 1991). Students also avoid asking questions because they “don’t want to look stupid” in front of their peers (Kemmerle, 2013). Unfortunately, students who most need the benefits of question asking are often the ones who are afraid to ask questions, and over time, lower-achieving students ask fewer and fewer questions (Good, Slavings, & Mason, 1988). The converse is true as well—confident students who feel empowered in their learning ask more and more questions over time and reap the benefits (Kemmerle, 2013). Pearson & West (1991) found that higher achieving students ask more substantive questions, and lower-achieving students ask more procedural questions.

Research has focused on student question asking in science education (see Marbach-Ad & Sokolove, 2000; Kelling, Polacek, & Ingram, 2009; Rop, 2002 for examples) and in English Language Arts instruction (see Rosenshine, Meister, & Chapman, 1996 for a review), and studies have looked at *teacher* questioning patterns in mathematics classrooms (see Boaler & Brodie, 2004; Boaler & Humphreys, 2005) but there are very few studies that specifically address *student* question asking in *mathematics* classrooms. The importance of the issue as well as the gap in the literature prompts my desire to contribute to this area. In order to better understand the dynamics around student question asking in mathematics lessons, it is helpful to develop understanding of the different kinds of questions students ask while they are learning mathematics. This paper presents analysis and a categorization of such questions. In order to do this, I observed six middle school and high school mathematics classrooms and collected all student questions that arose during my observations. This produced 1,737 student questions which were grouped into 15 distinct categories. Initial inter-rater reliability came in at 74% which caused a further refinement of the codes until full agreement was reached. Details of the categorization follow.

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Methods

Data Collection and Analysis

The study focused upon six classrooms chosen to offer a variety of instructional styles. The choice of substantially different learning environments enabled me to compare, contrast, and synthesize student questions across the cases (Miles and Huberman, 1994). See Table 1 for a summary of the six participants.

Table 1: The Six Teachers in this Study

Teacher	Grade	School and Classroom Information
Mr. Cordoba	8th	Small charter school in an urban district; 100% of students eligible for free/reduced lunch; mostly Latino/Hispanic student body; teacher focus on social justice and an “open” approach to mathematics (Boaler, 1998); approximately 50% of class time spent in small groups
Ms. Lyndon	7th	STEM middle school in an urban district with an emphasis on design thinking methodologies; 60% of students eligible for free/reduced lunch; student population is mostly Latino/Hispanic, Asian, and White; approximately 75% of class time spent in small groups
Mr. Ezzo	6th	Affluent suburban middle school where only 4% of students qualify for free/reduced lunch and student population is mostly white; teacher espouses a fairly “traditional” approach to instruction; teacher encourages his students daily to ask many questions.
Ms. Gibson	$10^{th}/12^{th}$	Medium sized high school in a mostly white but economically diverse school district; teacher uses a non-traditional curriculum designed to blend algebra, geometry, trigonometry, statistics in a four-year mathematics sequence
Ms. Kapoor	9th	Nationally-ranked, large high school in an extremely affluent suburban area; mostly white and Asian student population; classroom instruction consists mostly of lecture and note-taking; school culture is extremely competitive
Ms. Chang	10th	Independent day and boarding school for students who will be the first in their families to go to college; located in a historically underserved neighborhood; teacher blends traditional with innovative methods of instruction and values self-efficacy and sense-making

Data for this study consisted of approximately 45 hours of transcribed videotape, extensive field notes, semi-structured interviews with classroom teachers, and student surveys. I went through several iterations of transcription of the videotapes—during the first pass through the videos, I highlighted all student questions in the dialogue and took notes about each student question, thinking carefully about the function of each student question (Saxe, 1991). After I had worked through all the transcripts once, I went back and open-coded them again, using what I had learned the first time through the transcripts. I started to see patterns and similarities in the student questions and further refined my codes as I worked through more and more transcripts (Glaser and Strauss, 1967). I collaborated with my research group (Engle, Conant, & Greeno, 2007) about possible functions or purposes of student questions. We considered specific student questions that might epitomize a certain kind of question, in other words, a “case” of a kind of question (Shulman, 1992). I used the transcripts from my interviews with each teacher to gain more insight into their thoughts and feelings about how student questions affect mathematics instruction and student learning and to understand

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more about why different types of student questions appear in different classrooms. Lastly, I used short-answer responses from student surveys to hear directly from students about their experiences asking questions in their mathematics lessons and to triangulate my findings.

Results

What types of questions did students ask?

I begin by describing each of the classroom contexts and illustrating the types of questions that were asked in each of these classrooms. Mr. Cordoba believes students should be "active participants in mathematical activity through generating and discussing mathematical ideas in class." He presents his students with tasks that require high cognitive demand (Smith & Stein, 1998), and asks them to collaborate (more than half of class time is spent in small group work). See Table 2 for a small sample of questions Mr. Cordoba's students asked during my observation along with my initial codes for each question. The curiosity in Mr. Cordoba's students' questions and the desire to extend mathematical ideas to slightly different situations is notable. Mr. Cordoba's students also asked questions with the goal of helping each other learn.

Table 2: Questions from Mr. Cordoba's classroom

Student Question	My initial code
Can I rephrase his question?	Helpful to classmate/community building
Can k be an odd number, like 27, and could you still have *x* and *y* the same number?	Mathematical curiosity question; also seeking specific information
If *k* were to be bigger and the *k* was a negative, where would it be?	True extension question--student is changing a few components of the problem and thinking about what that would mean
What is your equation to figure out *y*?	Seeking procedural/algorithm information
How did you get *k* is zero?	Seeking conceptual information
How does it show it in the trend line? Would it ever cross the *x* line?	Mathematically curious question/Representation question; seeking conceptual information
Does your *y* have to be negative?	Seeking conceptual information, explanation, meaning
Can your *x* be bigger, like if your number is 24 or lower, can the number you're multiplying be bigger and multiply by a decimal?	Another true extension question. Also shows mathematical curiosity

Ms. Lyndon's approach to teaching mathematics is to emphasize sense-making, intellectual risk taking, and mathematical communication in her classroom. Ms. Lyndon's students spend the majority of class time collaborating on group-worthy tasks (Cohen & Lotan, 2014). Ms. Lyndon intentionally and consistently teaches her students how to ask each other questions and how to work together to solve problems. See Table 3 for a sample of student questions from Ms. Lyndon's classroom and note that her students ask questions that think critically about various approaches to problems. They seek to make connections from one idea to the next and they want to find the best or most efficient approach to a problem.

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Table 3: Questions from Ms. Lyndon's classroom

Student Question	My initial code
How does this relate to Alyson's method?	A question that connects a new mathematical idea to something already known/ A different approach question
In the corners, should we write *n-1*?	Student is wanting to know what teacher expects for the presentation of the work
So how did you get your picture?	Student wants to understand a visual representation of the mathematics
What's useful about this?	Mathematically curious question; also seeking connection to other mathematics, other subjects, or the real world
How did you get 34?	This could be a question that only seeks for procedural information, but looking closely at the context reveals that the student is trying to understand conceptually
Wait, why did you minus it?	Student trying to understand the mathematical procedure
I'm confused about *x*. What does *x* mean?	Asking for clarification
What's good about this method?	Procedure/algorithm question, but it's more than just asking how to do something; it's thinking critically about the merits of the method itself

Mr. Ezzo's approach is what some might call traditional: every day class begins with a scoring of the previous night's homework, followed by a lecture on new material. Mr. Ezzo espouses a "closed" (Boaler, 1998) approach to mathematics in that each student is expected to solve mostly context-free problems each day in the precise way they are taught by their teacher. See Table 4 for a sample of student questions from Mr. Ezzo's classroom and note that in Mr. Ezzo's class, many students are focused on getting the right answer, pleasing the teacher, and making sure they score well on homework and exams.

Table 4: Questions from Mr. Ezzo's classroom

Student Question	My initial code
I did 2 and 75 hundredths, does it count?	Meeting teacher's expectations (about presentation of answer)
What was the answer to 23 again?	Seeking information about a correct answer
Wait, how is it 3 out of 5?	Seeking meaning/conceptual information
Should we copy that down?	Classroom routine/meeting teacher's expectations about note-taking
Could we also just do 4 over 10?	Clarification question—this feels conceptual, knowing that 4/10 is equivalent to 2/5; this question is also focused on form of the answer
Once you find the first one, don't you just have to keep adding it on to find the next one?	Question about a procedural/method
Do you think we'll be able to do some homework in class?	Classroom routine question
Is it okay if I do it the way you just showed us?	Seeking go-ahead for a particular method
Can we do any of these ways on the test?	Assessment question

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Ms. Gibson considers herself a math reformer and uses a non-traditional curriculum that "requires a great deal of collaboration, investigation, experimentation, and question asking." Ms. Gibson expects her students to present their mathematical thinking at the board each day and she emphasizes sense-making and a safe learning environment. See Table 5 for a sample of student questions from her classroom. These questions suggest that Ms. Gibson's students want to understand the mathematics conceptually and also to know how the mathematics is useful.

Table 5: Questions from Ms. Gibson's classroom

Student Question	My Initial Code
Why are you finding the inverse?	Seeking conceptual information
Are all the lines called curves on a graph?	Question about terminology
I don't understand that last part. Why do we need the 225?	Seeking conceptual information, seeking to understand
Don't we need two measures to find the minor arc and don't we only have one?	Clarification, trying to better understand the procedure
Would you put this kind on the test?	Assessment
Do you want me to try to explain?	Community building
I have a question about when I would use a t-table, like at a job.	Application to real world

Ms. Kapoor's classroom follows a traditional format of homework review, new lecture, and new homework. For the most part, Ms. Kapoor students sit quietly and take notes throughout instruction. Ms. Kapoor states that she wants her students to be ready for college and "expects a lot" from her students. Ms. Kapoor's tests are known to be extremely difficult. Table 6 offers a sample of student questions from Ms. Kapoor's classroom. These questions suggest that Ms. Kapoor's students are anxious to please her and to score well on assignments and exams.

Table 6: Questions from Ms. Kapoor's students

Student Questions	My initial Code
When do we get the test back?	Seeking information about assessment, indicates concern for his/her grade
Is this right?	Seeking confirmation of a correct answer or method
Is there a calculus [state] test? What's the last year we have to take it?	Seeking information about an assessment
How many pages are on the test?	Question about assessment
Where do you want us to turn this in?	Classroom routine, meeting teacher expectations
Do you want us to draw it or label all the points?	Note-taking question, shows desire to please teacher
Wouldn't you have to do the angle bisector, inscribe the circle, and then do some nightmarish math?	Seeking confirmation of a method/procedure/approach
"What's the center of the triangle, would that be the orthotriangle? Circumcenter?"	Terminology question
"This just occurred to me, when it says counterclockwise 90 degrees, does that mean around the origin?"	Seeking information about meaning, conceptual information
"So what do I do here?"	Seeking information about procedure

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Finally, Ms. Chang, the youngest of all six teachers, recently earned her teaching credential at a teacher education program that focuses on teaching for understanding. She states that she wants all her students to "understand the math on a deep level." The mathematics department at her school developed the curriculum she uses, and Ms. Chang expects all her students to participate actively each day by taking notes, asking questions, and presenting problems at the board. Table 7 shows student questions from Ms. Chang's classroom. These questions suggest that Ms. Chang's are interested in getting the right answer and understanding and exploring the mathematics.

Table 7: Questions from Ms. Chang's classroom

Student Questions	My Initial Code
"Did I do it right?"	The student seeks confirmation from the teacher that she is correct.
"Is it okay to graph the original one first, and then shift it?"	Seeking information/approval about a method or approach
"Why is the period still 2π?"	Seeking conceptual information
"If the 2 was a ½, would it be a stretch?"	The student is exploring and speculating mathematically. Mathematically curious question; extension question
"Can I explain?"	Community building
"Do you put that in increments of π if you were to label it?"	Representation/notation question
"So, what is a phase shift?"	Terminology question
"How many points are on the quiz?"	Assessment question

As I observed and analyzed the student questions in Ms. Kapoor's and Ms. Chang's classrooms, I realized that no unusual or unexpected student questions emerged, thus indicating that I had reached data saturation (Marshall, 1996; Guest, Bunce, & Johnson, 2006). I thus stopped data collection and focused my efforts on refining, naming, and describing my categories. When determining the boundaries of each student question category, I thought carefully about the specific functions different questions served for the students asking them (Saxe, 1991). After many iterations of sorting and thinking about names for the categories, I produced 15 categories (See Table 8).

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Table 8: Not All Questions are Alike—Student Question Categorization

Question Category	Examples from Transcripts
Form of Answer	-Do I have to show it as a repeating decimal, or can I round up?
Correct Answer	-But what is the answer? -I got 3 and 7 tenths, does it count?
Assessment/Grading	-Could I get extra credit for this? -How many points are on the quiz?
Meeting Teacher's Expectations	-Wait, do we copy down the percents bar model too? -Did I do it right?
Seeking Procedural[1] Information	-How did you get 16? -What is your shortcut for filling in your t-table?
Seeking Conceptual[1] Information	-Why did you have to cross out the 40 and the 10? -Why is the period still 2π? -Why are you finding the inverse?
Visual Representation --Conceptual --Informational	-If your x were to get bigger and then the trend line, would your points, can it ever cross the x line? -Where would it be on the graph? -Do you put that in increments of π if you were to label it?
Community Building	-Can I rephrase his question? -Do you want me to explain?
Making Connections	-How does this connect with what Alyson did? -Did you all use the same method to find all of your k's?
Mathematical Curiosity/ Extension	-Can k be an odd number, like 27, and could you still have x and y be the same number? -If k were to be bigger and the k was negative, where would it be? - If the 2 was a ½, would it be a stretch?
Terminology	-So what is a phase shift? -What's the center of the triangle, would that be the orthotriangle? Circumcenter? -Are all the lines called curves on a graph?
Application to Real-World	-I have a question about when I would use a t-table, like at a job. -What's useful about this?
Clarification/Confirmation	-Do you mean like that there is only some in the positive side and none in the negative side?
Notation	-Should I write f(x) or y?
Classroom Routine	-Can we go over 9? -Will there be time at the end to work on homework?

Conclusion

In this paper, I present a categorization schema for student questions within mathematics lessons. Such a categorization helps define and articulate differences between the various types of questions students ask in mathematics lessons. This tool can help researchers, educators, and teachers think more carefully and analytically about the student questions within mathematics lessons. This type of analysis will potentially lead to deeper, more conceptual, more curious mathematical questions from students.

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Endnotes

[1]The difference between Seeking Procedural Information and Seeking Conceptual information is difficult without the context. While it is usually possible to identify the other categories with just the question alone, these two categories are often hard to differentiate without the before and after dialogue.

References

Boaler, J. (1998). Open and closed mathematics: Student experiences and understandings. *Journal for Research in Mathematics Education*, *29*(1), 41-62.

Boaler, J., & Brodie, K. (2004). The importance, nature, and impact of teacher questions. In D. E. McDougall & J. A. Ross (Eds.), *Proceedings of the Twenty-Sixth annual meeting of the North American Chapter of the International Group of Psychology of Mathematics Education* (Vol. 2, pp. 773-782). Toronto, Ontario, Canada: McDougall & Ross.

Boaler J., & Humphreys, C. (2005). *Connecting mathematical ideas: Middle school video cases to support teaching and learning*. Portsmouth, NH: Heinemann.

Cohen, E., & Lotan, R. (2014). *Designing groupwork: Strategies for the heterogeneous classroom*. New York, NY: Teachers College Press.

Daly, J. A., Kreier, P. O., & Roghaar, L. A. (1994). Question-asking comfort: Explorations of demography of communication in the eighth grade classroom. *Communication Education*, *43*(1), 27-41.

Engle, R., Conant, F., & Greeno, J. (2007). Progressive refinement of hypotheses in video-supported research. In R. Goldman, R. Pea, B. Barron, & S. Derry (Eds.), *Video research in the learning sciences* (pp. 239-254). Mahway, NJ: Lawrence Erlbaum Associates.

Glaser, B., & Strauss, A. (1967). *The discovery of grounded theory*. Hawthorne, NY: Aldine de Gruyter.

Good, T. L., Slavings, R. L., & Mason, D. A. (1988). Learning to ask questions: Grade and school effects. *Teaching and Teacher Education*, *4*(4), 363-378.

Guest, G., Bunce, A., & Johnson, L. (2006). How many interviews are enough? An experiment with data saturation and variability. *Field Methods*, *18*(1), 59-82.

Kelling, E., Polacek, K., & Ingram, E. (2009). A statistical analysis of student questions in a cell biology laboratory. *Life Sciences Education*, *8*(2), 131-139.

Kemmerle, M. (2013). Promoting student questions: A high school mathematics case study. In M. V. Martinez & A. Castro Superfine (Eds.), *Proceedings of the 35th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 1004-1011). Chicago, IL: University of Illinois at Chicago.

Marbach-Ad, G., & Sokolove, P. (2000). Can undergraduate biology students learn to ask higher level questions? *Journal of Research in Science Teaching*, *37*(8), 854-870.

Marshall, M. (1996). Sampling for qualitative research. *Family Practice*, *13*(6), 522-525.

Miles, M., & Huberman, A. (1994). *Qualitative data analysis: An expanded sourcebook*. Thousand Oaks, CA: Sage.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.

Pearson, J., & West, R. (1991). An initial investigation of the effects of gender on student questions in the classroom: Developing a descriptive base. *Communication Education*, *40*(1), 22-32.

Rop, C. (2002). The meaning of student inquiry questions: a teacher's beliefs and responses. *International Journal of Science Education*, *24*(7), 717-736.

Rosenshine, B., Meister, C., & Chapman, S. (1996). Teaching students to generate questions: A review of the intervention studies. *Review of Educational Research*, *66*(2), 181-221.

Saxe, G. B. (1991). *Culture and cognitive development: Studies in mathematical understanding*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Shulman, L. (1992). Toward a pedagogy of cases. In J. H. Schulman (Ed.), *Case methods in teacher education* (pp. 1-30). New York: Teachers College Press.

Stein, M. K., & Smith, M. S. (1998). Mathematical tasks as a framework for reflection. *Mathematics Teaching in the Middle School*, *3*(4), 268-275.

Stipek, D., Salmon, J. M., Givvin, K. B., Kazemi, E., Saxe, G., & MacGyvers, V. L. (1998). The value (and convergence) of practices suggested by motivation research and promoted by mathematics education reformers. *Journal for Research in Mathematics Education*, *29*(4), 465-488.

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