Posing Purposeful Questions Through Making Sense of Mathematical Tasks

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Through post-observation and general discussions our preservice teachers thought they were asking good questions by asking "why?". While these questions are important, "why?" questions are not always effective, especially when a student responds with "I don't know". Such questioning techniques must be explicitly taught and practiced through the lesson planning phase. We used a situation that occurred during one of our preservice teacher's field lesson as a teachable moment for questioning techniques. We explored the nature of classroom discourse with the preservice teachers examining their own experiences through the lens of three question types: generating discussions, probing, and exploring relationships.

Many mathematics teachers believe that students learn through sharing their ideas, listening to and critiquing the ideas of others, and by having others critique their approaches to solving problems. Classroom discussions in which these activities occur do not materialize out of thin air" (Smith & Stein, 2011, p. 69). While many practicing mathematics teachers have this belief, we have learned that our preservice teachers often have difficulties in facilitating classroom discussions and asking appropriate questions during their field experience lessons. Before our preservice teachers teach their lessons, they meet with their Cooperating Teacher (CT) to obtain the standard, topic, and necessary resources. The preservice teachers then compile that information into one of our lesson plan templates. Both templates include the general information of a lesson plan such as standards and objectives, a section for Higher Order Thinking questions using Bloom's Taxonomy (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956), a section where the students script their thinking or approach to the lesson, their formative/summative assessments, ESOL/ESE modifications, a lesson closure and a post-lesson reflection. We also observe our preservice teachers through physical or video observations to provide feedback on their overall lesson.

After observing a few lessons, we realized that most of our preservice teachers struggled with questioning their students and responding to questions asked by their students. We understand that good questioning can either encourage new ideas or result in students recalling basic and lower level information (Moyer& Milewicz, 2002). Most of our preservice teachers thought they were asking good questions by simply asking "why?". While these questions are important, "why?" questions are not always effective, especially when a student responds with "I don't know". Such questioning techniques must be explicitly taught and practiced through the lesson planning phase. Another layer of difficulty our preservice teachers encounter involves asking appropriate questions during their mathematics lessons. Interacting with and questioning students during mathematics lessons tends to be more difficult for preservice teachers due to different approaches to solving a problem, multiple solutions of some problems, lack of knowledge in understanding how students think mathematically, and low comfort level of their own understanding of certain mathematical concepts (Ball, 1991; Lampert, 1986; Ma, 1999; Moyer & Milewicz, 2002; Nilssen, Gudmundsdottir, & Wangsmo-Cappelen, 1995).

Instructional Task

We used a situation that occurred during one of our preservice teacher's field lesson as a teachable moment for questioning techniques. We set up the discussion using the following example and shared the general information from the lesson plan. The preservice teacher provided students with the following problem: ***Pizza Task***

Jack and Jill ordered two medium pizzas, one cheese and one pepperoni. Jack ate 5/6 of a pizza, and Jill ate 1/2 of a pizza. How much pizza did they eat together? *Solve using a visual model (i.e. drawing) and/or manipulatives. Be prepared to explain and justify.* The student learning outcome for the lesson was *students will construct a viable argument to defend their visual solution when adding or subtracting fractions.* We were careful not to identify the preservice teacher who taught this lesson as this was time for constructive feedback and learning for the next lesson to be taught. We told the preservice teachers that several students shouted out that Jack and Jill ate 1 1/3 pizzas. We asked the students three questions: Is the solution correct? How should you respond? What is your next instructional move?

In our courses, we focus on modeling techniques and strategies for our preservice teachers. There is a time for lecture, however, our preservice teachers benefit from practical applications. We discussed how to go beyond accepting a student's one word answer to requiring students to explain and reflect on their thinking. We emphasized that the key to exploring student's explanations and reflections is the use of purposeful questions. Each question must be intentional as "effective teaching of mathematics uses purposeful questions to assess and advance students' reasoning and sense making about important mathematical ideas and relationships. (National Council of Teachers of Mathematics, 2014, p. 35). Prior to exploring the types of questions, we wanted to explore and model the lesson used in the field by the preservice using the actual pizza task mentioned above.

Why Instructional Tasks Matter

We informed our preservice teachers that good tasks drive instruction and asked them to first consider whether the task being utilized was in fact a "good" task? We defined a "good" task as a task that will elicit procedures with connections, a task which allows students to "do mathematics" (Ball, Thames, & Phelps, 2008; Carpenter, Fennema, Franke, Levi & Empson, 2015; Stein & Grover, 1996). Smith and Stein (1998) posit there are two levels of demand as it relates to task selection: lower-level demand and higher-level demand. While our preservice teachers were familiar with the definitions; where lower-level demand tasks focus on memorization and procedures without connections and where higher-level demand tasks focus on procedures with connections and doing mathematics; they could not transfer this knowledge to their lesson plans and instructional tasks. We discussed how the selection of a higher-level demand tasks was the precursor to having a productive discussion, as "tasks that are focused on limited thinking and reasoning are unlikely to highlight key mathematical ideas" (Smith & Stein, 2011, p. 20).

After a whole group discussion, our preservice teachers concluded that the pizza task would be considered as a higher-level demand task as it required students to explore and understand the nature of the mathematical task. Hiebert and Wearne (1993) suggested two factors that impact teaching and learning: instructional tasks and nature of classroom discourse. We explored the latter with our preservice teachers examining classroom discourse through the lens of three question types. Since we wanted our preservice teachers to gain both the experience of learning how to ask purposeful questions and practicing the content, we provided time for them to work on the task in class. Question types being posed in the classroom setting "impact the nature and flow of classroom discussions and the cognitive opportunities offered to students" (Boaler and Brodie, 2004, p. 781). During the mathematics instruction discussion using the pizza task we followed the suggestions of Smith and Stein (2011) using three of the nine types of questions used by teachers (Boaler & Brodie, 2004) to unpack the lesson. What follows are the three question types (see Table 1) being modeled and explored using the pizza task with our preservice teachers.

Table 1
Types of Questions Used by Teacher

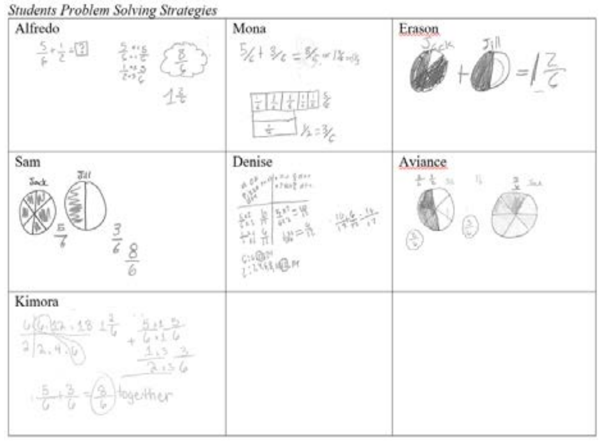
Question Type	Description
Generating Discussion	Solicits contributions from other members of class.
Probing, getting students to explain their thinking	Asks student to articulate, elaborate or clarify ideas.
Exploring mathematical meanings and/or relationships	Points to underlying mathematical relationships and meanings. Makes links between mathematical ideas and representations.

Source: Excerpt of Teacher Questions Developed by Boaler & Brodie, (2004)

The Questioning Experience

As our preservice teachers worked on the task individually and then compared their answers with a partner, we walked around with clipboards arranging the solutions and problem-solving strategies in the order we wanted to discuss with the whole group. We then called on individual preservice teachers to share their work. Table 2 includes several of the preservice teacher's solutions and strategies that were shared with the whole class via the document camera. These problem-solving strategies were selected to demonstrate a variety of problem solving methods.

Table 2
Students Problem Solving Strategies



We have included the dialogue that took place with our preservice teachers based on the question types. We modeled each question type with real discussions.

Generating Discussion (excerpt)

Author 1: What did you do?

Erason: I drew Jack's pizza then I drew Jill's pizza. In my head, I put the two together and got 1 2/6.

Author 2: I see you were writing out multiples, please explain.

Denise: I knew I needed to find a number for both 6 and 2. So I wrote out the multiples of 6 and the multiples of 2. I saw that 12 was the same for both. I then multiplied 5/6 by 2/2 because 12 was the second number. I then multiplied 1/2 by 6/6 because 12 was the sixth number. I got 10/12 and 6/12 and added to get 16/12.

Probing, Getting Students to Explain Their Thinking (excerpt)

Author 2: How did you know to place the 1/2 below the 1/6's?

Mona: I first drew out 5/6. I knew 1/2 was the same as 3/6. So, I put it below the 3 of the 1/6's on the number line. I then counted the 1/6's and had 8 1/6's. To get 8/6.

Author 2: Alfredo, why did you write 8/6 and 1 2/6?

Alfredo: When using the formula, I got a common denominator of 6. When I combined the numerators I got 8. So, it was 8/6. But I heard you say to another student think in terms of the pizza. Which made me realize 8/6 means I have a whole pizza with 2 extra. So that's why I wrote 1 2/6.

Exploring Mathematical Meanings and/or Relationships (excerpt)

Author 1: Kimora, you found a least common multiple (LCM) of 6 and Denise found a LCM of 12. What is the LCM?

Kimora: I noticed Denise wrote out the multiples of 2 and 6 just like me. She has 6 as a multiple of both 2 and 6. But she also noticed 12 is a multiple also.

Author 1: Denise, what is Kimora saying.

Denise: She is saying that we both correctly listed the multiplies of 2 and 6. Even though I found a multiple of 2 and 6 to be 12, the least common multiple is 6. Therefore, I could have reduced my answer.

Author 1: Aviance, what is similar between Sam and Kimora's work?

Aviance: Sam drew 5/6 of a pizza and Kimora just wrote 5/6. Sam knew 1/2 was equal to 3/6 and Kimora found an equivalent fraction. They both had 6 equal parts and combined the numerators to get 8/6.

Author 1: Aviance, how does yours compare?

Aviance: I did the same thing as Sam, but I broke Jill's pizza into 6 equal parts to match Jack's 6 parts. So, instead of having 1/2 of a pizza shown, I now have 3/6 of a pizza shown.

Author 1: Erason, what are you thinking?

Erason: I noticed Denise did 12ths. I could have drawn 12ths too. But 6ths were simpler to do. Also, I just realized I could have simplified my 2/6 to 1/3.

Author 1: Why would you simplify?

Erason: Because 2/6 is equivalent to 1/3.

Author 1: Which one is right though?

Erason: Both

Author 1: Class, turn and talk to your shoulder partner, should it be 2/6 or 1/3?

{Wait Time}

Mona: They are the same. But the directions say create a visual. And the visual would should 2/6. Because both pizza's must be made into equal parts to combine.

We asked our preservice teachers if they noticed any similarities and/or differences between our interactions with their classmates. As a group, they noticed how our questions went beyond the standard question type of gathering information and the typical questions that would yield yes/no responses. We asked them to generate a list of questions they expected us to ask or questions that they would have normally asked during their field experience lessons. The preservice teachers mentioned questions such as:

- Did you get 8/6?
- Should we find a common denominator first?
- Does 1 2/6 simplify to 1 1/3

Prior to the exposure of the three question types, our preservice teachers thought they were doing a good job engaging the students in their lessons and asking questions to determine the student's level of understanding. We mentioned that most types of questioning would be a good start and we applauded them for attempting to generate some student discourse. We reviewed the three question types and explicitly talked them through the process of how we selected the order of how their classmates presented their strategy and reminded them of each question we asked during each dialogue for each question type. We wanted our preservice teachers to have an opportunity to process their experience as a student solving a higher-level demand fraction task and then as future teachers who are learning how to ask purposeful questions during a mathematics lesson. We stated that to have rich mathematical discourse, questioning must go beyond recalling facts, procedures, and definitions (NCTM, 2014). As a closing activity, we asked our preservice teachers to consider the types of questions their Cooperating Teachers tend to ask in the classrooms they observe. We asked if the questions focused on recall or pressing into students thinking? In their lesson plans, we asked the preservice to use the chart (Table 1) to identify the question type(s) they wanted to incorporate and use the descriptions to justify their thinking. Using the NCTM's (2014) purposeful questions as a guide we reviewed some questions and tips (see Table 3) that we wanted our preservice teachers to plan for and use in their next mathematics field lessons.

Table 3
Sample Questions and Tips

Questions	Tips
What did you do? Why did you do it?	Utilize higher-demand tasks that lend themselves to rich discourse.
How could you solve this problem a different way?	Ask questions that build on prior knowledge or previous responses.
How does your solution pathway compare/contrast to your classmates?	Allow wait time for students to process the information and think of an approach.
Could this be situation be applied to something else? How?	Be intentional with the questions that are being asked that will make student thinking visible.

Conclusion

At the end of the activity and lecture we wanted our preservice teachers to understand that the key to purposeful questioning is intentionality. Purposeful questioning will not occur through happenstance. These questions will help guide the unpacking of the mathematical task during individual, small-group, and whole-class discussion. It is imperative to incorporate questions that lead discussions to move beyond focusing on students merely obtaining the correct answer, to discussions that focus on making sense of the problem-solving process. Focusing questions on the problem-solving process helps to enrich student's mathematical experiences by allowing the mathematics to move beyond just "numbers" and "formulas" to a beautiful concept that is based upon problem-solving.

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