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Networks An On-line Journal for Teacher Research

The Value of Why for Student and Teacher Learning

Jody Guarino, Marie Sykes, and Rossella Santagata

We believe teaching for understanding begins with the development of a few essential orientations. Teachers must have an appreciation for student-centered mathematics teaching, valuing an approach that builds on student thinking. In addition, teachers must appreciate the complexity of students' mathematical thinking and ideas. Once these orientations are in place we can attend to student thinking in ways that draw inferences about their understanding (Carpenter, Fennema, Peterson & Carey, 1988; Ma, 1999) and use those inferences to further probe, uncover and extend the complexities of student thinking. We contend this is possible through the value of "why." Asking "why?" when teaching mathematics has benefits for both students and teachers. The benefits for students have been highlighted by several authors (Hufferd-Ackles, Fuson, & Sherin 2004; Lampert 2001; Stein, Engle, Smith, & Hughes 2008; Stein, Smith, Henningsen, & Silver 2000). Among others, Hiebert and colleagues (1997) discuss how through the verbalization of their thinking students reach deeper understanding of the mathematical ideas they are working with. When students are asked to reflect on their thinking they form new relationships among mathematical ideas and check old ones. In addition, when student thinking is made visible in the classroom, opportunities are created for students to challenge each other's ideas and ask for clarification. In this paper, we illustrate these benefits through a classroom example.

Asking "why?" when teaching has also benefits for teachers. Others have argued that teachers need to reflect on their practices and be intentional in the instructional choices they make (Cochran-Smith & Lytle, 1999; Zeichner, 1994; Schon, 1983). To illustrate this point, we will introduce a project centered on the idea that asking "why?" allows teachers to learn from their daily work in the classroom. This paper invites the reader into the classroom of the teacher-researcher who worked collaboratively with university researchers and faculty who were engaged in similar work with preservice teachers to determine the instructional power of "why." We represent a range of roles in educating students and teachers. Marie is a full-time classroom teacher and a mentor teacher to preservice teachers. Jody is an elementary classroom teacher, university lecturer in a multiple-subjects teacher education program, and mentor teacher to preservice teachers. Rossella is a professor and researcher, studying preservice and in-service teacher learning. Our collaboration continues to lead us to new understandings that inform each of our work with students, preservice, and in-service teachers, both at our elementary school sites and in the university setting.

One of the most critical elements in teaching as we are proposing, where student thinking is made visible, is the depth of rich information we can elicit from student thinking. Our students provide us with critical insight into their understandings and misunderstandings of mathematical concepts. In the beginning of a study of fractions in Marie's second and third grade classroom, David, a third grader, posed the question, "Can 6/8 be simplified?" David's question was recorded on a sticky note and added to the "Burning Questions" chart in the classroom. David's second and third grade classroom is from a high-performing elementary school in a large southern California district, and as a combination class, it was made up of strong students from each grade level. Throughout the study of fractions, students' burning questions were continually revisited, with new questions added, existing questions revisited, and new conjectures challenged.

David's question, "Can 6/8 be simplified?" was revisited and used as a springboard for classroom discourse as the unit progressed. The following exchange revealed critical insights into student thinking, including misconceptions of the concepts of simplifying and decomposing.

Marie (classroom teacher) (M): Can 6/8 be simplified? Show me with a thumbs up or thumbs down.
All students show thumbs up. (Note: There could be a tendency for teachers to stop here.)
M: How do you know when a fraction can be simplified?
Alexa: There are four 2's in 8 (4 x 2 = 8) and there are three 2's in 6 (3 x 2=6), so 6/8 could be simplified to ¾.
M: What do we look for when we simplify a fraction?
Jake: Like you can divide it to make a fraction.
M: Divide it by what?
Jake: 2
M: Always 2?
Jake: Yes.
M: Can we simplify ½? Show me with a thumbs up or down if you think we can simplify ½.
Students show mixed responses.
M: So how would you simplify ½?
Austin: ½ could be broken into ¼ and ¼.
M: Are you saying ½ can be simplified into ¼ and ¼? Is this simplifying or is this something different?
Sam: We're breaking it down into ¼'s.
M: Why can we do that? Why can we break ½ into ¼ and ¼?
McKell: Because if we take ¼ and ¼ it equals ½.
M: How do you know?
Maddy: Because ¼ and ¼ is the same as 2/4.
Jake: I think it's just decomposing because 2/4 and ½ are equivalent fractions. Pretty much what I'm saying is ½ is made of 2/4.
M: When we say decompose, what do we mean? What is our thinking about decomposing?
Carrie: It's breaking apart.
M: So when we're simplifying a fraction, what are we doing? Are we breaking it down into its parts?
Carrie: We're finding equivalent fractions.

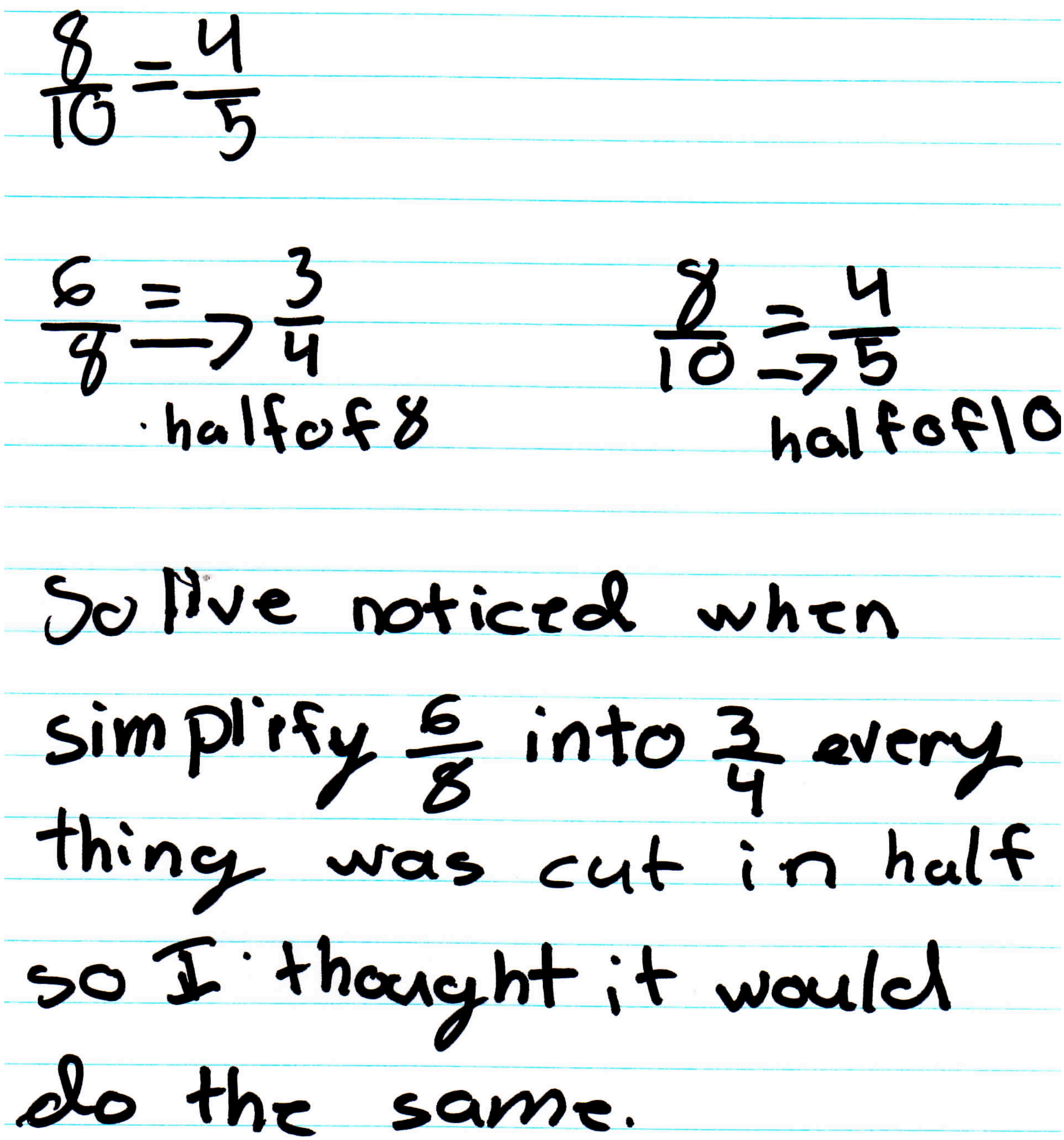
At the beginning of the above exchange, students indicated with a "thumbs up" that 6/8 could be simplified. Marie could have stopped there with a surface level understanding of student thinking, believing that all students had an understanding of the concept. By continuing to elicit student thinking with probing and clarifying questions such as "why"and "how?" , student levels of understanding became evident, as did misconceptions. For example, several students understood decomposing, or breaking apart numbers, but were confusing this process with simplification of fractions. When Marie asked her students how they knew when a fraction could be simplified, generalizations and misconceptions became apparent. For example, Carrie labeled the process of simplifying fractions as "finding equivalent fractions." Asking "why" provided Marie with an opportunity to examine mathematical understanding beyond a surface level. It also provided Marie with the information needed to facilitate student-directed instruction thereby leading her students to develop a deeper understanding of fractions.

During this process students also examine the basis for their thinking. As a result, the surfacing of underlying misconceptions enabled both Marie and students to probe deeper. This is evident with Jake's misconception that fractions can be simplified if they can be divided by two, and only two. It is also evident in Trevor's thoughts below. When posed with the problem, 8/10 = ___/5, Trevor explained, "I saw that 6/8 was simplified to ¾. 3 is half of 6 and 4 is half of 8, so I thought, 5 is half of 10. I thought the numerator would also have to be turned in half and I knew 4 is half of 8." (See Figure 1, Trevor's journal)

The following classroom discourse resulted from Trevor's explanation.

M: Trevor saw a pattern when we simplified the other fractions… What do you think about Trevor's thinking?

Carrie: I think the strategy he used was pretty efficient.


$\frac{8}{10} = \frac{4}{5}$

$\frac{6}{8} = \rightarrow \frac{3}{4}$ half of 8

$\frac{8}{10} = \rightarrow \frac{4}{5}$ half of 10

So I've noticed when simplify $\frac{6}{8}$ into $\frac{3}{4}$ every thing was cut in half so I thought it would do the same.

Figure 1. Trevor's Journal

M: Trevor, do you think to simplify a fraction we just take a fraction and break it in half and that's simplifying it?
M: Class, what if I give you the fraction 6/9? Show me with thumbs up, thumbs down…can you simplify 6/9?
Students show mixed responses
M: A lot of you are saying no. Why do you think we cannot simplify 6/9?
Eric: If you go back to whole numbers, well for the fractions it's odd, the denominator is odd.

M: Are you saying that if a denominator is an odd number it cannot be simplified?

Eric: Yeah because, you can't break odd numbers into half.

Austin: 6/9 can't be simplified because 9 can't be divided by 2.

M: So is your conjecture that a number has to be divided by 2 to be simplified? Raise your hand if that is your thinking right now…a fraction has to be divided by 2 to be simplified. Who thinks that right now?

Alexa: I think it can be simplified.

M: Why?

Alexa: I was thinking that 3x3=9 and 3x2=6.

M: So how can that be simplified?

Alexa: Into 2/3

M: But what about what Trevor said? If you can break the numerator in half and break the denominator in half then you can simplify? Trevor, what do you think about that?

Trevor: I'm not disagreeing with myself, but now I'm thinking that will only work with even numbers because you can cut any even number in half but you can still simplify odd numbers.

Student Learning

"Why" questions call upon students to elaborate and explain their answers leading them to a deeper understanding of mathematical concepts. During the course of the class discussion, Trevor develops metacognitive skills as he adjusts his thinking, moving from a generalization to a more clarified understanding of simplification. He has discovered that while "halving" may be an effective strategy in simplifying some fractions, it is not a strategy that can be applied to simplifying all fractions. Trevor's understanding is supported by Kilpatrick, Swafford, and Findell (2001) who contend, "Children's math proficiency develops in two directions, one in which children use a strategy to solve a specific type of problem and second that children use a general strategy that can be applied to a class or classes of problems" (p. 186). Trevor and the other students in his class have also been engaged in developing essential skills for 21st Century Learning, critical thinking and problem solving skills, as they "analyze and evaluate multiple perspectives, interpret information, reflect creatively on processes, solve problems in conventional and innovative ways, and identify and ask questions that clarify the ideas of others" (Partnership for 21st Century Skills, 2009, p.4). The dynamics of asking questions allows both students and teachers the opportunity to question each other's thinking as well as their own, as evidenced in Trevor's conjecture. Multiple perspectives provide a valuable lens through which we are able to not only view, but to understand and reflect upon the basis of each other's thinking. Students are empowered as they learn that the teacher is not the only source of knowledge in the classroom. Each of us contributes to the learning and together we help each other develop our understanding. In addition, students have the opportunity to struggle as they develop understanding, an idea supported by Hiebert and Grouws (2007) as they explain,

When students struggle, within reason, they must work more actively and effortfully to make sense of the situation, which, in turn, leads them to construct interpretations more connected to what they already know and/or reexamine and restructure what they already know. This yields content and skills learned more deeply (p.389).

Working together to develop understanding through the "power of why" cultivates a culture of inquiry, provides a model for lifelong learning, and promotes a distinctively higher level of collaboration and cooperation. Ultimately, students need to arrive at the correct answer however, the process they engage in to get there is also important.

Teacher Learning

Focusing on "why" has benefits for teachers as well. When we ask students to make their thinking visible, we create opportunities for us to learn not only how students' reason about and understand mathematical ideas, but also to question our own understanding of these ideas and our instructional decisions. This is evident in Marie's reflections after teaching the lesson:

> *As the teacher of a second-third grade combination class facilitating the classroom discourse on simplification of fractions, my initial objective was to address the question posed by David and check for student understanding of the concept. We had been*

> *counting with fractions as well as working with fractions through problem solving involving equivalency and word problems. When I asked, "How do you know when a fraction can be simplified?" I learned that several of my students were making a generalization that simplifying fractions meant a fraction could be divided by 2 or in half. Based on their responses to my questioning, I chose to further probe their understanding by asking them if ½ could be simplified. As a result of that question, I discovered that several of my students were connecting their understanding of decomposing, or breaking fractions apart, with simplification. During the exchange with my students, I realized that their initial responses, their generalizations, about dividing fractions in half to simplify them was a direct result of the type of fractions I was presenting to them. As a result, I chose a fraction that could not be divided in half, 3/9, but could be simplified. Learning to learn with my students allows me to adjust my own mathematical thinking and instructional decisions.*

This reflection highlights how teachers can learn from their daily work in the classroom. When we engage intellectually in a dialogue with students we gain important insights about their understanding of mathematics that can inform our future instructional decisions and impact student learning. For example, Marie has learned that when working on fraction simplification, one has to be careful about what fractions are shown to students. While this time her students' misconception caught her by surprise, next time she will be more prepared and will know to present contrasting cases to students so they can move from using a strategy that works only in specific cases to a strategy that works across a class of cases (Kilpatrick, Swafford, and Findell, 2001). By asking "why" and by making student thinking visible, teachers collect evidence of student learning and understanding they can use to inform both on the spot and future instructional decisions (Santagata & Guarino, 2011).

Learning to Learn from Mathematics Teaching

This idea is at the center of a project we are working on collaboratively at California University and at Sienna Elementary School in Mission School District. The project is entitled: Learning to Learn from Mathematics Teaching (LLMT). It involves students enrolled in the elementary teacher preparation program and their master teachers. Through a series of activities that make use of videos of classroom lessons, interviews with individual students and samples of student work, future teachers learn to reflect on and analyze teaching in a disciplined manner (Santagata & Guarino, 2011; Santagata & Guarino, 2012). They learn that teaching can be an object of inquiry if teachers set up clear goals for their students, plan for activities that they hypothesize will assist students in reaching those goals, and collect a variety of evidence to monitor student progress (Hiebert, Morris, & Glass, 2003).

In order for preservice teachers to engage in productive analysis and reflection, we must develop their appreciation of student thinking and ideas and student-centered mathematics teaching (Santagata & Guarino, 2011). In addition, preservice teachers must acquire abilities to analyze teaching in productive ways. They must learn to attend to students and draw inferences about their mathematics understanding, recognize and understand strategies that make student thinking visible, and utilize evidence based reasoning to evaluate the effectiveness of teaching. Classroom exchanges, such as the one discussed above become the object of study. Figure 2 illustrates how that transcript and the corresponding student work can be used to develop pre-service teachers' orientations, knowledge, and skills for learning from teaching. The right column includes questions that guide pre-service teachers' collaborative analysis of the transcript and student work. The left column includes the corresponding orientations, knowledge, and skills that we intend for the process of analysis to develop.

Disciplined analysis is coupled with field-based experiences. Working as a pair in a master teacher classroom at Sienna Elementary School, preservice teachers engage in conversations similar to the ones they have at the university around artifacts of practice. By placing two student teachers in each master teacher classroom, we enhance the opportunities future teachers have to talk about teaching, exchange ideas, and work collaboratively. They first observe, then participate in, and finally lead mathematics lessons similar to the ones presented above. They then debrief by analyzing evidence of student learning and collaboratively make decisions on how to move forward. Our goal through this process is to provide early on

Orientations, Knowledge, and Skills	Guiding Questions
Attend to student thinking and strategies to make student thinking visible	What do you know about the understanding of specific students as suggested by the exchange? What student misconceptions emerged through the exchange? What can you infer about Trevor's understanding from his work sample? What is important about his thinking? Where in the transcript to you see an explicit attempt to develop a generalization about fractions?
Attend to strategies the teacher uses to make student thinking more effective	What was the teacher's role in the exchange? How did the teacher make student thinking visible? What instructional decisions did the teacher make and how did those decisions impact student learning? List questions asked by the teacher. Why do you think the teacher chose the fraction ½ to be simplified? Look for examples of probing questions. Where in the transcript did you see an explicit attempt to let students struggle?
Propose alternatives	What if the teacher had asked if 8/16 could be simplified instead of 6/9? How might the resulting interaction have been different? How might the next steps have changed? How else might the teacher challenge student thinking? How could you improve the exchange? What could the teacher do next and why?

Figure 2. Guiding Questions centered on Fraction Transcript

scaffolded opportunities for preservice teachers to study teaching so they can be on the right trajectory for becoming reflective practitioners. By asking "why" questions to their students and about their teaching, future teachers can learn general principles about teaching mathematics and student learning of mathematical ideas, thus engaging in a learning process similar to that of their students, who are generalizing mathematics solutions to classes of problems. Through cycles of planning, teaching, and reflection, pre-service teachers deepen their understanding of how students reason about key mathematical ideas and common student misconceptions. They also learn what instructional strategies, visual representations, and mathematical tasks better promote student understanding.

Initial evidence supports this approach to teacher preparation. Pre/post test studies have shown that preservice teachers improve their abilities to analyze teaching as portrayed in videotapes of classroom lessons by learning to attend to the details of student thinking and to reason about the impact of specific instructional strategies on student learning (Santagata, Zannoni, &Stigler, 2007; Santagata & Angelici, 2010; Santagata & Guarino, 2011). A study of preservice teachers' paired student teaching experience also supports this approach (Guarino, 2011). Data was collected from fifteen pre-service teachers, paired in one of their two fieldwork assignments. Eight participants were paired for their first fieldwork experience and seven were paired for their second. A wide range of undergraduate majors were reported by participants including seven social sciences majors, five arts and humanities majors, two liberal studies majors, and one business major. One participant had a masters degree in clinical psychology. Thirteen participants attended college in California, six of those at the university of the teacher preparation program. Fourteen participants attended public universities, and one attended a private university. Ages entering the teacher preparation program ranged from 22 to 48 years. Nine participants were 22 or 23 years, five participants were 24 to 28 years, and one participant was 48 years. Participants reported a variety of experiences working with children or in educational settings. Data included two individual semi-structured interviews. Participants were asked to describe how often they collaborated, what they collaborated about, and how the paired fieldwork experience contributed to their ability to analyze and reflect on teaching and learning. Interviews were recorded and transcribed. In addition to interviews, preservice teacher pairs were observed three times within their paired fieldwork assignment. Each observation consisted of submission of a written lesson plan prior to the observation, lesson observation, and post-observation conference. Interview data and observation data were examined to identify themes, patterns, similarities, and differences and inductive analysis (Patton, 2002) was used to identify themes. Several themes emerged from the analyses and what is most relevant to the topic of this paper is the role that dialogue between preservice teachers had for their professional growth. Participants were observed to engage collaboratively in analyses of student thinking and to discuss alternative instructional strategies both in the midst of instruction and as options for future lessons. Dialogue played a key role in this reflective practice as preservice teachers reported engaging in constant dialogue, from conversations about student learning, to discussions of student work samples and evidence of student understanding. They continually talked about students, their learning, and ways in which to further develop that learning. Many preservice teachers developed dispositions for continuous improvement. As one preservice teacher explained, "I've gone from not even knowing what it meant to reflect to enjoying analyzing things and learning from my mistakes. (Reflection) contributed to my ability to analyze my students." Another preservice teacher shared, "Now that I'm able to reflect, have a conversation about lessons, I feel like my reflective skills have really developed. When I worked individually I wasn't as strong a reflector and reflection is such a big part of a teacher's skill base, to be able to reflect on a lesson and then make changes and modify based on what happened. That skill is what's going to help you teach and reach the students. It's helped for my future career." (Santagata & Guarino, 2011; Santagata & Guarino, 2012.

Conclusions

Asking "why" emphasizes reflection, engaging both students and teachers in rich learning experiences. Students are free to take risks in their thinking as well as struggle to develop their own understanding. This allows them to make sense of mathematics in deeper ways.

By asking "why," teachers also take risks and explore possibilities with their students. As Marie reflected on the student discourse within this classroom exchange she developed an awareness of the importance of anticipating student misconceptions in the planning phase of her instruction. By attending more strategically to the numbers she chose to present to her students, misconceptions and overgeneralizations could have been foreseen and planned for. In her reflection she stated:

> *If I had examined my own thinking about fractions when planning and looked at it from a student's perspective, I would have made different instructional decisions. I would have chosen fractions that were not all representative of even numerators and denominators, choices that contributed to students' belief that simplification of fractions had to involve halving.*

Marie's reflections exemplify the type of reflective analysis we strive to have our preservice teachers achieve. Through this partnership, we have come to understand the impact strategic fieldwork placements, placing preservice teachers in classrooms of reflective practitioners such as Marie, and providing a framework for paired preservice teachers to analyze and reflect on their teaching in productive ways, can contribute to our end goal. As we have illustrated, using questioning to probe student thinking provides teachers with critical information that allows them to learn from their daily practices. When asking "why" is applied to the work of teaching, it develops practitioners who can exercise their professional judgment, assess the effectiveness of their strategies, and continue to improve over time.

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