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Communication: A Vital Skill of Mathematics

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Abstract

In this action research study of my classroom of seventh grade mathematics, I investigated the impact of communication in the classroom. I focused on asking more open-ended questions in the hopes that students would engage in mathematical discourse with a focus on correctly using mathematical vocabulary. I also looked at the level of students' understanding and achievement in mathematics class and the accuracy of students' assessments of their own understanding when there is a focus on asking and answering open-ended questions. I discovered that students had a better understanding of vocabulary when they were asked more open-ended questions. I also found that students felt a lot more comfortable about communicating with peers and teachers after being exposed to more open-ended questions. As a result of this research, I plan to continue encouraging student oral communication in my classroom. My students will be encouraged to use appropriate math vocabulary in their everyday oral communication. Students in my classroom will be exposed to more open-ended questions and will be asked to explain how they reached their conclusions using correct math vocabulary.

One issue that I see as a problem in my classroom is my students' ability to communicate their mathematical thinking. Most of my students are interested in just getting the answer without really understanding how they got there in the first place. I want my students to be able to communicate with their peers and their teachers. If students can communicate their steps and answer questions about how they reached the answer, then they have a good understanding of the topic. I do not want my students to see a math problem and start working right away to find an answer. Students need to be able to analyze the problem, find an appropriate method for solving, and then communicate those steps with the teacher or their peers.

In my class, I have students working together in small groups. Many times I have noticed myself walking around and hearing groups talking about anything else but math. I remind students that they are in groups to communicate with one another about math. It can be tough for students to ask questions or to admit that they do not understand, especially in front of an entire class. It is my intention, that in working in small groups, students will become more comfortable with their communication. I usually have students work on homework in groups, but I have not tried having students go over completed assessments and actually communicate with peers about problems that were missed. Allowing students the opportunity to communicate with their peers about what they did wrong could be very beneficial. I also would like my students to be able to communicate with me on what their mistakes were and how they could fix those problems.

Once students have learned a new topic, like most teachers, I check their understanding by giving homework problems and assessments. Once the assessments have been given, I do not usually have students go over their assessments with peers; instead, I try to go over assessments with students who did poorly. However, this usually consists of me showing them the correct way to solve the problem. I do not take the time to have the students communicate with me about

how they solved the problem. I try to analyze their work and the answer they give. Having students communicate to me can be very beneficial to their learning as well as to mine as an educator. This would show me to what extent each student can analyze and evaluate their mathematical thinking.

Also, by having students communicate their ideas, it gives the educator a chance to check their language. Vocabulary is one area that the math department at my middle school is trying to improve. I am spending more time reviewing vocabulary everyday in the classroom. I also am giving quarterly assessments to test the students over new and old vocabulary that they have learned up to that point. Teachers can check students' vocabulary usage through oral and written communication. Having a good math vocabulary would make expressing their ideas much easier. It is a goal of mine to have my students be able to organize their mathematical thinking and communicate with their peers and their teachers. This ability will be beneficial for me and for their future math teachers. It will be beneficial because they will be able to communicate their understanding with their teachers.

I want my students to be comfortable with mathematics. It is possible that at times, students are not comfortable with math because it has its own language. If a student does not understand the language, it can be frustrating. It is my goal to set my students up for success as much as possible by providing instruction to help them understand and be able to use the language of mathematics. The ability to communicate their ideas with peers and others gives the students a chance to show what they have learned. Once students can understand how to speak the language of mathematics, communicating their ideas will be a lot easier for them.

Problem Statement

Communication is a key part of students' learning. The communication skills that students learn now can benefit them in the future. According to the National Council of Teacher of Mathematics (NTCM), "Changes in the workplace increasingly demand teamwork, collaboration, and communication" (NCTM, 2000, p. 348). Students need to be able to communicate with their teachers and their peers. Understanding vocabulary can help to become better communicators. It is important that as an educator I am able to understand my students' knowledge of a mathematical concept. One way to do this is by asking open-ended questions. "Teachers can stimulate students' growth of mathematical knowledge through the ways they ask and respond to questions" (Piccolo, Harbaugh, Carter, Capraro, & Capraro, 2008, p. 380).

According to NCTM (2000), "Teachers must help students clarify their statements, focus carefully on problem conditions and mathematical explanations, and refine their ideas" (p. 351). Students need to feel comfortable talking about their understanding in order to become better students. As an educator, it is important that I do everything that I can to help students be comfortable in my classroom. The more comfortable they are, the more they may be willing to communicate. "Teachers are encouraged to provide opportunities for students to discuss their ideas about mathematics and to listen closely to what students say" (Sherin, 2000, p. 122). It is important to listen to students when they communicate so they can be encouraged and helped in their task of solving mathematical problems.

Communication is not just vital for the mathematics classroom, but in all classrooms. All educators know the importance of being able to communicate with students, to have students communicate with one another, and to have students understand what they are communicating about. "The need for meaningful classroom discourse is now universally accepted among

educational researchers, and teachers are encouraged to use ‘higher order’ questions” (Kabasakalian, 2007, p. 843). Both oral and written communications are key skills for any student. Educators have to be willing to push students to become good communicators.

Literature Review

Communication is an essential part of daily living. There are many forms of communication including written communication and oral communication. I use many forms of communication to teach my students. I expect communication from my students to help me know which materials they do or do not understand. Communication, or discourse, plays a big role in all classrooms including the mathematics classroom. In the following review, I looked at communication in the mathematics classroom. I focused on teacher communication with the students; student communication, both with peers and the teacher; and finally the oral and written communication of a mathematics classroom.

Teacher Communication

Good communication skills start with the teacher. “We know that mathematics instruction should be more than teachers’ writing on their chalkboards and explaining algorithms as they solve problems, hoping that students can follow along” (Piccolo, Harbaugh, Carter, Capraro, & Capraro, 2008, p. 376). Piccolo et al. researched student communication with peers and with teachers. During the three-year study, mathematics classrooms were videotaped to look at teacher-student discourse. The videotapes were then coded for the different types of questions that the teachers used to engage students in more meaningful discourse. In the study, it was determined that the teachers dominated the conversations when conversing with students. The students simply responded to the teacher’s questions without asking a lot of new questions. The students did a better job of communicating with their peers. They were able to talk about the

material being taught and made a lot of mathematical advancements in their discussion with their peers.

"Mathematics teachers have a long history as lecturers" (Van Zoest & Enyart, 1998, p. 150). It is important for teachers to look at their teaching to see how they are communicating with their students. Teachers should not be the only person communicating. Van Zoest and Enyart looked at one teacher's experience in the Mathematical Sciences Sequential Summer Institute sponsored by the National Science Foundation. The participants, which were all teachers, focused on discourse in their own classrooms by videotaping lessons and then analyzing the type of discourse that was occurring. One of the teachers from the study decided to look at her videos and to study the student responses. She found that her students understood more than what she thought. During class, the teacher thought that students did not understand the mathematical processes because she did not understand their questions. In fact, her students did understand most of process but could not clearly communicate their questions regarding the final answer. The teacher learned how important it is to listen to students and to ask them to clarify their questions and not give up on them.

Kabasakalian's (2007) study was based on the fact that the United States is not doing enough in teaching students mathematics. Kabasakalian found other research that looked at the importance of oral language in learning mathematics and also at problem solving and its role in oral language. She used these studies to help her in researching techniques that would help students become better problem-solvers. Her study was conducted while presenting at professional development activities with math teachers. While Kabasakalian was sharing information at a professional development course for teachers, she found that there was a lack of teacher content knowledge. Teachers in the professional development course were presented

with math problems and then their discussions for solving the problems were recorded and analyzed. The research ended up showing the importance of teachers' mathematical content knowledge. This knowledge can lead to meaningful discourse in the classroom for both the teacher and the student.

In my research, I looked at how my communication skills helped my students in becoming better mathematical communicators. I often find myself asking students questions that they can respond to with a simple one-word answer. Piccolo et al. (2008) agrees that questions requiring only short one-word answers are insufficient to generate discussion and suggests: "One method of stimulation is asking open-ended questions that are designed to initiate problem solving and aid conceptual understanding" (p. 380). It is important to ask students questions that allow them to show their understanding of the math content, and to this end, teacher listening skills are important as noted in Piccolo et al.'s study (2008). It is also important, as Kabasakalian (2007) suggests, that I have a good understanding of the mathematical content that I am teaching.

Student Communication

In addition to teacher communication, students' communication is an important part of mathematical discourse in the classroom. Student communication was an important part of Knuth and Peressini's (2001) research. They worked with classroom teachers for four years in order to help teachers realize the importance of more meaningful discourse in the classroom. The authors described one classroom teacher's discourse with students on two different occasions. In one vignette, the teacher led the students in a discussion, and in the other vignette, the teacher allowed the students to lead the discussion. From their research, Knuth and Peressini suggest that "students will acquire a deeper understanding of mathematics when they use their own statements, as well as those of their peers and teacher" (p. 325).

Sherin's (2000) article looked at one teacher's attempt to encourage more student discourse in the classroom. David, the teacher in the article, experimented with different techniques in order to encourage more discourse in the classroom. He wanted his students to be able to lead discussions while sticking to the mathematical concepts being taught. "Teachers are encouraged to provide opportunities for students to discuss their ideas about mathematics and to listen closely to what students say" (Sherin, 2000, p. 122). David, like most teachers, found it difficult to keep students on mathematical topics when they were leading the discussions. Student led discourse is not easy, but can be very beneficial for the students. "Once a teacher has seen students defending their mathematical ideas, questioning other students ideas, and helping clarify the mathematics to one another, the importance of discourse becomes clear" (Van Zoest & Enyart, 1998, p. 150).

Knuth and Peressini (2001) state that "in any social interaction involving spoken communication, each individual must both decipher what is said and generate his or her own meaning from it" (p. 325). In my classroom, students are very willing to accept what I say as the truth. They do not often question my teaching or the material that is being taught. My students are so willing to accept the answers in order to be done with the work. They always seem to be looking for the "easy way out." Students need to be involved in the classroom discussions in order to help them understand the material and to make connections for themselves. As Knuth and Peressini (2001) summarize well,

> "These calls for more meaningful discourse are grounded in the social nature of mathematics learning, a vision of school mathematics practices that reflects both the essence of practices in the discipline itself and the need for students to be able to communicate their mathematical knowledge in a technological society" (p. 321).

Oral and Written Communication

Students have not always had the opportunity to have meaningful discussions in their classrooms. In a study by Pape, Bell, and Yetkin (2003), they found that students' "learning histories rarely prepared them to take a more cognitively active role in the own learning" (p. 183). Pape et al. researched a seventh grade mathematics classroom. They were interested in finding ways to get students more actively involved in their own education. Communication, both oral and written, played a key role in this research. At the time of publication, the authors of the study found that the students they worked with were "now more able than previously to communicate mathematical understanding and justify their mathematical reasoning" (p. 196). During the study, the students were presented with many new strategies, including peer discussions and teacher-to-student discussions. These strategies helped students to have a better understanding of math and helped them to realize the importance of making good choices in their mathematical decisions.

"As students communicate their ideas, they learn to clarify, refine, and consolidate their thinking" (McIntosh, 1997, para. 3). McIntosh cites the NCTM standards in her article. She discusses that although not everyone agrees with the NCTM standards, most people could agree with the importance of communication in the mathematics classroom. McIntosh discusses the importance of students learning the signs, symbols, and terms of mathematics. Communication, whether oral or written, should become easy and natural for students once they understand the language that is to be used. McIntosh states: "This is best accomplished in problem situations in which students have an opportunity to read, write, and discuss ideas in which the use of the language of mathematics becomes natural" (p. 1).

Capraro and Joffrion (2006) discuss how children can learn the meanings of words through everyday experiences using both oral and written language. Capraro and Joffrion were interested in determining the success rate of middle school students when translating written words into algebraic equations. They researched seventh and eighth grade students for a year by giving pre-tests and post-tests that consisted of multiple choice and short answer questions. Students need to have time to process information that is given to them, either through oral or written communication. The results of the research showed that students need to understand the information given before solving the problem. “Reading in mathematics necessitates that one understand the meaning of the words” (p. 162).

Oral and written communication can be very useful in the mathematics classroom. As Pape et al. (2003) found in their research, students have a better grasp of their own understanding when they are able to communicate their ideas. It is important for students to have good communication skills in the classroom because they then can use this skill to justify their work. Capraro and Joffrion (2006) also researched the importance of communication with appropriate vocabulary. Students need to have some ability in communication in order to enhance their understanding of the mathematics language.

Conclusion

Pape et al. (2003) focused on 29 seventh grade students who were enrolled in a pre-algebra class. My research is similar in the fact that I also researched seventh grade students enrolled in my pre-algebra class. The students from Pape et al. had above-average mathematical experiences and ability. Some of the students in my class are considered above average as according to their test scores, which include their ITBS scores and district math test scores. My research looked at ways to help my students become better oral communicators and written

communicators. I also worked on asking students more open-ended questions, similar to the research conducted by Piccolo et al. (2008).

My students filled out forms prior to quizzes to help them with their written communicational skills, which is similar to the technique that Pape et al. (2003) used. The form that I had students fill out before quizzes is very similar to the form that the teachers used in Pape et al.'s research. This gave students a chance to evaluate their own understanding of the math topics. It also gave them a chance to communicate their understanding to me. This was helpful for me to evaluate which areas the students needed more practice.

Piccolo et al.'s (2008) research looked at students ability to communicate with certain topics of math, including integers, fractions, and decimals. Although I teach these topics and they are important areas of math, I was more interested in my students' communicational skills of all areas in math. My students were asked to lead discussions in the classroom, which is similar to that of the study done by Sherin (2000). However, there were clear expectations of the appropriate topics for discussion. Students were not allowed to stray too far off topic before I stopped them. In Sherin's study, the teacher David had difficulty with classroom discussions because he had problems with keeping students on topic.

Purpose Statement

This project was meant to help me, as an educator, realize how important it is for my students to be able to communicate. Before this research, I was a teacher who stood at the front of the room and taught my students math. I might ask a few of them to come to the board to show their work, but I never really asked them to explain their work. Students not only need to be able to come up with an answer; they need to understand how they reached the answer. I also wanted to use this project to help my students to improve their mathematic vocabulary and their

communication. In order to better understand my role in bringing about these changes for my students, I investigated my teaching practices by asking: What will happen to my teaching when I focus on asking my students more open-ended questions and teach them to engage in mathematical discourse, with a focus on correctly using mathematical vocabulary?

I was interested in knowing the impact of these changes in communication in my classroom and I wanted to make sure that my students were improving in their skills in my classroom. Consequently, I researched: What will happen to the level of students understanding and achievement in mathematics class when students ask and answer open-ended questions?

Not only was it important for me and my students to become better communicators, I also wanted my students to see the importance. I knew that I would be able to assess their learning through assessments, but I wanted the students to be able to judge for themselves just how the communication helped them in their learning. To this end I investigated the research question: What will happen to the accuracy of students' assessments of their own understanding when there is a focus in math class on asking and answering open-ended questions?

Method

I collected data during the spring semester of the 2008-2009 school year. The data was collected from my first period class which consisted of 30 students. This was the pre-algebra, or the advanced, seventh grade math class. The data collection process was different depending on the research question I was trying to answer. One method always remained the same, my personal teacher journal. This is where a lot of my data collection was recorded. I kept a spiral notebook on my desk at all times. I had a set of questions that I kept in mind while journaling (see Appendix A). This helped me to stay focused. I could quickly write down notes evaluating

my daily teaching. I also carried the notebook with me while observing my students individually and in group settings.

The journal came in handy when I was working with students. I would be able to keep accurate account of which students I helped and which groups the students were working in. This way, I had a chance to see if a student's communication skills changed depending on their group arrangement. I also used the notebook to keep track of conversations that I overheard while walking around my classroom. I was very interested in listening to the dialogue between students without stepping in to the conversation. I tried to distance myself sometimes from these conversations in order to be a spectator. It really opened my eyes to the communication skills of my students with their peers. Not only did I use the notebook to keep track of conversations I heard, but I also used a rubric (see Appendix B). I used the rubric to keep track of how students were working in their groups. It helped me to see if group members were using appropriate vocabulary, if group members were helping one another, and if they were able to work together by answering and asking open-ended questions.

Placing students in groups was a great way to document students' communication skills with their peers. However, I also wanted to look at students' communication skills with me. I did this by conducting interviews with students during our study hall time. I interviewed 3 to 4 students at a time. I would randomly choose students from the class list and bring them into my room for interviews. Due to time and other responsibilities during study hall I only interviewed one group per study hall. I conducted these five interviews on Tuesdays. Some of these interviews went better than others. There was one interview that was interrupted due to a fire drill. Some of the interviews were not used in my research because I did not get any answers to my questions that helped me in answering my research questions.

These interviews would begin by reviewing the students' homework assignments. First I would do a quick review, and then the students had a chance to ask me questions about problems they found to be difficult. From this point, the students and I would have mathematical conversations. I was able to discuss the students' feelings toward math and the way that their communication helped them succeed in math.

The interviews were great, because I was able to ask a lot of open-ended questions. It was not just me teaching the students. From the interview, which is really just a conversation, the students' ability to use vocabulary became very important. I also had some pre-written questions that I tried to ask the students during every interview (see Appendix C). These questions gave me some insight as to how the students liked or did not like working in groups. I was also able to see how the students' confidence was changing. I asked the same questions on March 3 and then again April 7. I made sure to interview the same group of students on these two dates so that I could compare their answers.

I also collected students' homework. The homework was a great tool because I was able to look at students' homework to check their written communication. In each section of a chapter, there was always one problem that is called the "Error Analysis" problem. These problems are great because it gives the students a chance to be the teacher. There is an example of a problem that was solved incorrectly. The students' job is to clearly explain the mistake and then fix the problem. I was able to keep track of how students were using vocabulary on these problems in my teacher journal throughout my research. There were a set of questions that I followed to make sure that the students were fixing their mistakes (see Appendix D). This was a tool that my department used on certain sections and assessments. It helped us as a department to find the strengths and the weaknesses of our students.

Before any assessment, students filled out forms (see Appendix E). They had to tell me what grade they thought they would earn on the assessment and what material they thought would be covered on the assessment. Students were also asked to fill the form out after the assessment. The students were able to compare how they thought they would do on the assessment with how they truly performed. One of these forms was filled out on March 12 and March 14. The students took a story problem assessment on the 13th of March. The day prior to the assessments, the students filled out the survey. The students had the opportunity to assess their knowledge of the assessment. The following day, the students filled out the form again after they had seen their graded assessment.

The assessments that were given to students were recorded into a grade book. I kept track of each student's individual assessment scores and their performance on the assessments throughout the research period. Some of the assessments were handed back to the students; however, I kept the major tests. These were kept as evidence on how the students were progressing.

It was a lot of work to conduct a research project while teaching. I found that in many of my journals, I did not write as much as I would have liked to. Most of this was due to the time factor. Some of the journals just did not paint a good enough picture of what I was seeing or feeling during the time of data collection. It was hard to write down everything that I wanted due to time. I also started by just writing down what I thought was enough, but then realized that if someone else read the journals, there was not a clear picture of what my room looked like. It was very stressful to have two roles, teacher and researcher. I sometimes would get so involved in the teaching that I would forget about the research. There were time when the lesson was going so

well that I just kept teaching and did not really pay attention to keeping track of what was going on in my room.

There were some parts of the data collection that went very smoothly. For instance, asking questions during the interviews or giving the students surveys went well. The students go used to filling out the surveys before assessments. In fact, there were a couple of times that I forgot to give them the surveys, and some of the students made sure to remind me. That was great because the students were getting a lot of use out of the pre-test and post-test surveys.

Findings

Having a routine everyday was very important to me. Students knew what was expected of them on a daily basis. My students knew that everyday there would be a set of problems for them to solve on the back board in my room. These daily problems were called “Bellwork.” The “Bellwork” was a school-wide assignment. Every class had a set of problems, usually three to 10, for students to work on when they entered the room. This gave the students a chance to prepare for the day’s lessons, and also it gave the teacher a chance to take roll and to do a quick review with the students. My students then volunteered to work the “Bellwork” problems on the front board.

After we have finished the “Bellwork,” we then took a look at the homework assignment from the previous day. The students always had a chance to ask me a few questions. They knew that they needed to attempt all the problems that were assigned, but if there were a few that they did not finish, then they had a chance to work on them with me before the next lesson started. If the students did not have any questions for me, I asked them questions. I liked to have the students up at the board as much as I could.

When the students were finished with the questions from the homework assignment, I began the new lesson. I tried to always tie in the previous day's lesson to the new lesson. This helped the students see the connections within mathematics. I tried to start with the basics of the lessons, almost like a review, before I jumped into the heart of the lesson. After I taught the lesson, I gave the students examples to work. The examples that I gave them to work on were usually problems straight from the new homework assignment. I think that gave the students a chance to feel successful because they were guaranteed to get some of the problems from the homework correct if they were paying attention in class.

One of my research questions looked at my teaching. I wanted to know what would happen to my teaching when I focused on asking my students more open-ended questions and teaching them to engage in mathematical discourse, with a focus on correctly using mathematical vocabulary. Through my journals, daily and weekly, and experiences in the classroom, I found that it became much easier for me to ask open-ended questions to my students. I noticed at the beginning of the journals I reminded myself numerous times to make sure that I asked more questions of the students. On February 27, I wrote to myself: "I have not gotten used to asking the students questions that are open-ended. It is taking me some time learning how to ask my students to explain their answers without just telling me this is the answer." Although this was the first week of my research, I still made several notes in the beginning of March to phrase sentences differently or questions differently. In April, there were fewer notes to myself about how I should ask questions and more about not asking too many questions so that my students would get enough work time. Now, I know that I ask the students to tell me or to show me how they reached their answer. I know that in the past I would accept their answers and move on to

the next questions, but as time went on, I caught myself several times asking students how they reached their answer or how they worked the problem without even thinking about it.

I also know that I have been working hard on making sure to use correct vocabulary at all times. I noticed that the students started to use more correct vocabulary. As I stated in my journal on March 13:

> "I feel that my students' vocabulary is increasing due to the increased communication that is happening in the classroom. I feel that students are not only increasing their communication with me, but they are also increasing their communication with their peers. I have noticed this a lot more when I walk around and observe group work that is going on in the room."

The students' communication was increasing. They were using a lot more vocabulary words that they were a few weeks ago. I also noticed an increase in vocabulary usage during the interviews that I conducted with students.

On March 3, during my conversation with a group of students regarding homework, the students were limited on their vocabulary usage. I could tell that they were trying but they were not all confident enough to use it.

> **Wichelt:** What questions do you guys have?
> **Student A:** I am really confused about what we have to show.
> **Wichelt:** Would any of the rest of you like to explain to (Student A) what your work should show?
> **Student B:** I would like to but I am also confused. Why can't we just put an answer?
> **Student C:** Mrs. Wichelt would like to make sure that we know what we are doing. If we don't show any work, then we can't prove that we know what we were doing. We could have just guessed the right answer.
> **Student D:** The work on these problems will help us to be able to solve harder problems, like the ones we will probably see on the test.
> **Student A:** So we have to circle all the key words that we see in a problem?
> **Wichelt:** Yes, I would like you to. That way, if you miss a problem, it is much easier for me to see your work. Also, when I go back to try and help you, I can have an idea of where you were coming from.
> **Student B:** So on number 2, the key words like increased by and product would be key words to circle?
> **Wichelt:** Why do you think that those are key words?
> **Student C:** They are key words because they indicate an operation.

Student D: Like increased by means to add and product means to multiply.
Student A: So that means that somewhere in the problem, in order to solve it, I will need to add and multiply to find the answer?
Student C: Yes, this looks like we will have a two-step equation to solve here.
Student B: Shouldn't we circle is as well?
Wichelt: What does is imply?
Student A and C: Is means equals.
Wichelt: Correct! I see one more key word.
Student D: a number
Wichelt: Which means?
Student B: That indicates where the variable should go.

On April 7, the students' vocabulary was much more precise. They were using the vocabulary words as if they were part of their everyday vocabulary. They were much more comfortable with using words like product, quotient, sum, and difference.

Wichelt: Do you have any questions today?
Student D: No not really.
Student B: I think I have it figured out.
Wichelt: How about you two?
Student A and Student C: Nope.
Mrs. Wichelt: Okay, well I have a few questions for you guys then. Take out a white board and a marker and let us go over a few examples that I have written down here. I would like you to copy the sentence that I have here, circle the key words, write an appropriate equation to solve the problem and then show your answer. I will be asking each of you to explain a part of the problem to me.

Here is a copy of the sentence that I gave the students to solve:

Ryan earned $20 dollars mowing his grandma's yard. Matt also mowed his grandma's yard. Matt's pay for his day of work is $10 less than twice the amount of Ryan's earnings. How much did Matt's grandma pay him to mow her yard?

Student A: This is easy Mrs. Wichelt!!
Mrs. Wichelt: Well then, (Student A), tell me what are the first key words that seem important to you?
Student A: Well, I noticed the key word "is" first, because that is where the equal sign goes. I also noticed the word "of" which means multiplication. However I see that there are two "of's" which means that I need to read the rest of the words around the words "of" to make sure that they really do mean multiplication.
Mrs. Wichelt: (Student B), what does (Student A) mean about reading around the word "of" to look for clues?
Student B: Well, for the word "of" to mean multiplication it needs to be standing alone. For instance, the first "of" does not mean multiplication because it is describing what

> Matt was paid for. He was paid for his day of work. Therefore it does not mean multiplication.
> **Mrs. Wichelt:** (Student C), does the other "of" mean multiplication then?
> **Student C:** No it does not, because it tells us what to take twice of, twice of Ryan's earnings. Therefore, of does not mean to multiply, but twice does.
> **Mrs. Wichelt:** (Student D) what key words did you find?
> **Student D:** I also noticed the "is" and "twice," but there is also the words "less than" which tell me to subtract and to switch the order of how things are written. Whatever I read first goes behind the subtraction sign and whatever I read second goes in front of the subtraction sign.

The ability to communicate with students was beneficial. I was able to see how the students' vocabulary was improving.

I was also interested in learning what would happen to the level of students' understanding and achievement in mathematics class when students asked and answered open-ended questions. It was very important to me to engage my students in the discussion in my class. I wanted them to feel that they were a part of the class and not just spectators. I looked at my journals and noticed that over time, the students were more comfortable with my questions. On April 3, I noted to myself in my journal:

> "The students are doing a great job of answering y questions. On Tuesday of this week, I asked students to set up a proportion for me to solve a problem. One student came to the front and showed her work and explained how she set up the problem. I then asked the rest of the class if they agreed. I had lots of hands in the air and students were willing to tell me why they agreed and then I had 2 students who came to the front to show how they set up their proportions. Then, as a class we had a great conversation about how all 3 proportions on the board were actually the same proportions because the work in the end was the exact same. It was awesome how involved the students were in defending their work."

It took some time for them to realize that they could not just answer the problem and be done. They were going to have to be able to explain their reasoning.

I also noticed from my journals and the students' homework that my students understanding of math increased. One example of increased understanding of vocabulary comes

from my March 25 journal: “(A student) was very confused about how to use the words *less than* to solve a problem.” Later I wrote about the same student on April 9: “(A student) was observed showing another student the correct way to interpret the words *less than* and how to use them in order to solve the problem.”After just a few short weeks of working with the class and this one student, this student was able to take what was learned and help another student. This was a great example for me because I felt that if this student could correctly explain how to use a vocabulary word that was confusing to them just a few short weeks ago, then this student has truly learned how to correctly interpret the vocabulary word.

I also noticed that my students were using more vocabulary words and more complete sentences in their daily homework on the “Error Analysis” problems. On March 2, a student wrote the following for his or her answer to his or her “Error Analysis” problem: “I think they added wrong so I fixed it.” I explained to the entire class that they needed to give me more of an explanation. They needed to explain the mistakes in more than just five words or so. On March 31, the same student answered his or her “Error Analysis” problem with the following explanation:

> “The person working this problem did not correctly interpret the meaning of the numbers used in the problem. They tried to use the number 1600 in the problem. This is not correct because 1600 is describing the type of race that was run by the person in the story. It is not a number that should be used to figure out how much longer it took the person to run a 1600 meter race the second time that she ran. Their sum is incorrect because of the use of 1600 in the problem.”

This was a great example of how the students were doing a better job of defending their answers and how to correctly fix someone’s mistake.

This was recorded in my grade book. Students were not receiving full credit for these problems at the beginning of the research but were doing much better toward the end. At the beginning of the research, about 10% of the students were correctly answering these problems,

but by April around 80% of the students were correctly answering the "Error Analysis" problems. They were not just fixing the mistakes but actually writing in detail what went wrong and how to fix it. The example from above shows how at the beginning of the research, I would typically get answers of "they added wrong, here's how to fix it." Then, toward the end of the research, the students' answers were more complete and used correct math vocabulary.

Observing group work was another useful tool to measure my students understanding. I noticed that over time, the students seemed a lot more comfortable using vocabulary words and justifying their answer to their peers. At the beginning of the research, the students were fairly quiet in the groups. On March 6 I noted in my journal:

> "(Student A, Student B, Student C, and Student D) should not work together in a group. (Student A) dominates the conversation and is not giving the rest of the group members a chance to speak. The rest of the group members seem very unsure of the work that is expected and are not talking at all."

I noticed that there would be one or two leaders among a group of four, but toward the end of the research every member of the group was speaking. On April 24 I noted:

> "There were many groups that were doing a great job of including each other in the conversation. (Student E, Student F, Student G, and Student H) did a great job of helping each other out giving each other a chance to speak. Each student in this group wanted to speak and give their explanation for their answer. If they disagreed, then they spoke nicely to each other and explained why they disagreed without arguing."

It seemed that everyone had something that they wanted to contribute to the conversation.

I used the rubric found in Appendix B to keep track of students' communication with their peers. During the first two weeks of the observation, the average groups score on the rubric was 8 out of 16. This was due to the fact that the students were not speaking to one another, and they were not using appropriate math vocabulary. During the last two weeks of observation, the groups' scores were much better. Most groups were scoring 12 out of 16. The students were

getting better at communicating with one another. However, most groups were only asking two or fewer open-ended questions, which were keeping them from scoring a 4 on this section of the rubric. Since the score improved, the level of communication was improving in the classroom. The students were more comfortable with not only answering my open-ended questions, but also with asking one another open-ended questions. They were interested in how their classmates reached an answer and wanted to hear from their peers.

Not only was it important for me to be able to notice the change in my students mathematical understanding and achievement, but I also wanted to know what would happen to the accuracy of students' assessments of their own understanding when there was focus in math class on asking and answering open-ended questions. The best data for this research question was the survey that I gave to students to fill out before and after assessments (see Appendix E). Students had a chance to assess the own understanding. I also used the students' assessments and homework as evidence for this, but these data collections did not show me what they students felt they had learned. My data related to this question was inconclusive. While my surveys supported that the students' accuracy increased when there was more of a focus in math class on asking and answering open-ended questions, the students' assessments and homework did not.

I gave students the first survey on March 6 and a majority of the students said that they would score 3 out of 4 on the assessment. Most of the students knew the material that would be covered but felt that they would not be *advanced*, or score a 4, on the assessment. However, when I gave them the assessment back, and they filled out the post-assessment survey, most of the students scored a 4. This was interesting to me because I noticed that the students did not seem very confident in their skills but actually did have the skills to perform well. When I gave the survey again on April 29, nearly all students said that they thought they would score a 4 on

the assessment. It turned out that all 30 students scored a 4. The students were able to do a much better job of assessing their understanding of the math. The assessments were also a useful data collection device. I was able to look at students quizzes to see how they were preparing for the tests.

Conclusion

I found that my classroom seemed to run a lot better when the students had been exposed to the open-ended questions. It took some time for them to get used to the idea of having to justify their answers. My students seemed a lot more comfortable in the classroom when they understood the material better.

Piccolo et al. (2008) stated that mathematics instruction was more than just teachers teaching. Teachers need to be actively involved in the classroom just as much as the students. I found this to be true in my classroom. I had to be involved in the classroom by asking my students to defend their answers and to explain more. I could not just accept their answers and move on; I had to listen to their reasoning and try to involve other students in the process.

Like Piccolo et al., I found that students did a better job communicating with their peers than with me at the beginning of my research. I was not just the lecturer, like Van Zoest and Enyart (1998) stated that math teachers have a history of being. I was part of their learning just as much as they were a part of mine. I really enjoyed having the students defend their answers, just like Sherin (2000) did in his study. It gave me a whole new insight to student learning and my teaching.

I think that Van Zoest and Enyart (1998) said it best when they said, “Once a teacher has seen students defending their mathematical ideas, questioning other students ideas, and helping clarify the mathematics to one another, the importance of discourse becomes clear” (p. 150).

Toward the end of my research, I really began to see the importance of communication in the classroom. The students really seemed to be understanding that just giving answers was not enough. It really became clear to me when the students began to ask open-ended questions to one another. They were really interested in understanding their peers' work and trying to figure out if the way they worked a problem matched someone else's thinking, even if they did not start solving the problem in the same way. The students really enjoyed listening and explaining to one another. There was a few times when the students actually asked me to defend an answer better than what I had done because they did not feel that I had explained enough of my work.

Implications

This research showed me how important it was for students to be a part of the lesson and to take an active role in their learning. I plan to continue teaching using open-ended questions. I want to know how my students are processing the information and what information they are learning. The best way that I can do that is to have them defend how they are answering. The students need to know and be held accountable for their understanding. I want students to use correct vocabulary to enhance their understanding of the mathematical language.

I will continue to use the pre-test and post-test surveys so that my students can assess their own understanding. I believe that these surveys give the students a chance to really look at their learning and to take part in their education. The students have a chance to see what they need to work on to improve. The students have a chance to review the information and to take time to assess their understanding.

I will not use the rubric for group work as much as I did during the research. Although I found it useful, it does take a lot of time. I may use it once in a while, but I honestly felt that I had a better understanding of the groups work just by observing. The more time I spent with each

group, the better idea I had of their abilities. I also would change some of the requirements of the rubric. I think that as the year goes on, I should change the rubric to match their ability. If the communication is improving in the classroom, then they should all be getting perfect scores. Therefore, I may need to change the number of open-ended questions that they need to ask or the number of appropriate vocabulary words that they need to use. I think that I would get much better data if I started expecting better communication from the students at the beginning of the year.

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Appendix A

Personal Weekly Journal Prompts

1. What questions seemed to get the students more involved in communication?

2. Which lessons seemed to be more successful this week? What went really well?

3. What changes have I noticed in my students this week?

Appendix B

Rubric Used for Group Observations

Rubric Used for Group Observations				
	4	**3**	**2**	**1**
Ability to Work with Group Members	All group members are involved and working together at grade or above grade level	Most group members are involved and working together at grade level	Few group members are involved and working together at or below grade level	Members are not working together
Vocabulary	Group successfully uses 4 or more vocabulary words to express mathematical knowledge	Group uses 3 or 4 vocabulary words to express mathematical knowledge	Group uses 1 or 2 vocabulary words to express mathematical knowledge	Group does not use any vocabulary words to express mathematical knowledge
Questions Posed in Group Meeting	Group members successfully ask 3 or more open-ended questions	Group members ask 2 open-ended questions	Group members ask 1 open-ended question	Group members do not ask any open-ended questions
Ability to Answer Group Members Questions	Group is successful at answering questions posed by group members and all member agree	Group is able to reach an answer posed by a group member but not all group members agree	Group is able to reach an answer posed by a group member but only with help from teacher	Group is unable to reach an answer posed by a group member

4 – Advanced
3 – Proficient
2 – Progressing
1 – Beginning
(The 4-3-2-1 scale is used school wide for grading purposes)

Appendix C

Questions for Student Interviews

1. What can I do as your teacher to help you understand math better?

2. Do you feel more comfortable working in groups or by yourself? Why?

3. Which students in this class do you feel more comfortable working with in small groups?

4. How has your confidence in math changed? Why do you think this is?

Appendix D

Collection of Student Work

The following problems were missed by more than 5 or more students in each class:

The common mistakes on these problems were:

After fixing mistakes, the following problems were still missed by more than 5 students:

Appendix E

Student Survey for Before and After Quiz

(Adapted from Developing Mathematical Thinking and Self-Regulated Learning: A Teaching Experiment in a Seventh-Grade Mathematics Classroom

Day Before Quiz

1. The quiz tomorrow will cover the following topics:_____

   _____

2. What should you do to study for the quiz:_____

   _____

3. What grade do you think you will earn on the quiz (Circle one of the following grades):

   1 2 3 4

Day After Quiz

1. What did you do to study for the quiz:_____

   _____

2. What grade did you actually earn on the quiz (Circle one of the following grade):

   1 2 3 4

3. Is this grade different than what you thought you would earn? If so, why do you think that is? (List a few reasons as to why you think your grade is different than what you thought it would be.) _____

   _____

4. Which questions do you need to work on before you retake the quiz? _____

   _____

Author's Response to Buddy Notes

1. My first draft was very basic in the fact that there was not a lot of detail. I basically just wanted to get a few ideas down for each heading. By the end, after many revisions and proofreading, the paper seems to have a lot of detail and proof of my findings.
2. I tried to make sure that the paper flowed. I felt that I knew a lot about the data and wanted to make sure that someone who didn't would be able to walk in and read the paper. I tried to make sure that I didn't leave anything out that would be important for someone else who wasn't there for the research.
   I also paid attention to my grammar problems as I don't feel that I am a strong writer.
3. I used a lot of Michaela's suggestions in my paper. There were many sentences that I thought made sense but the wording was confusing for her. She also helped me to find contractions and to make sure that I changed them. She also helped me on making sure that I had the correct tense of the words that I used. I used just about all of her suggestions
4. I think the strengths in my paper were my ability to show the methods that I used to research my findings. I really feel that I did a good job of using the different methods and making sure that they were done correctly.
   My key challenges as I wrote were trying to make sure that someone else would be able to understand my paper. It was very helpful to have someone other than me to read through the paper. There were things that I thought made sense but for someone else they didn't.
   If I had more time, I would continue to develop the findings sections more. I think that I made a good point as to what I found but I think that there could be more written here.
5. I would give Michaela a 2. She was very helpful and thorough with her reviews. She made sure that I understood what she was trying to say.