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Discourse and Cooperative Learning in the Math Classroom

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Abstract

In this action research study of my 6th grade math classroom I investigated the effects of increased student discourse and cooperative learning on the students' ability to explain and understand math concepts and problem solving, as well as its effects on their use of vocabulary and written explanations. I also investigated how it affected students' attitudes. I discovered that increased student discourse and cooperative learning resulted in positive changes in students' attitudes about their ability to explain and understand math, as well as their actual ability to explain and understand math concepts. Evidence in regard to use of vocabulary and written explanations generally showed little change, but this may have been related to insufficient data. As a result of this research, I plan to continue to use cooperative learning groups and increased student discourse as a teaching practice in all of my math classes. I also plan to include training on cooperative learning strategies as well as more emphasis on vocabulary and writing in my math classroom.

John Holt, an American author and educator once said, "The biggest enemy of learning is the talking teacher." These words, along with the famous Confucious quote, "I hear and I forget. I see and I remember. I do and I understand," help to illustrate my thoughts about how I believe that students learn. I have always felt the need to keep my students actively involved in learning, but also felt the need to retain order in my classroom. As I started to reflect on how my students were learning, I realized that I was actively participating in teaching math, but I wasn't sure that my students were actively participating in learning math. Therefore, in this action research study I investigated how the use of increased student discourse and cooperative learning would affect students' ability to understand and explain mathematical concepts and problems, as well as affect their general attitudes about math. The study, which lasted approximately 7 weeks, took place in my own 6th grade math classroom where I have taught 4-6th grade math for the past 6 years. The study involved 17 students, 9 male and 8 female. All of the students are in the regular math classroom, but 3 also receive some Title I assistance. For this research project, I played the role of both teacher and researcher. As a researcher I conducted student pre and post interviews and surveys, collected teacher and student journals/reflections, and videotaped several lessons involving both small and whole classroom discussion. The journals and videotapes were further analyzed using rubrics and/or analytic codes.

PROBLEM OF PRACTICE

I have often heard that to question is to begin to understand. I have personally found that when I am starting to understand something I am better able to ask questions about it, but if I am confronted with something that I don't have a clue about, I don't even know where to begin asking questions. I often remind students of this as they are learning something new and I generally make the assumption that if students are starting to ask questions they are also beginning to have an understanding of the concept. I have also encouraged my students to know "why" we are learning something. To really understand math and problem solving, students must internalize the concepts and be able to explain why we do things as we do. How can I get students to express verbally or in writing why or how they arrived at an answer, why an answer may be correct/incorrect, and what questions they continue to have about a math concept that has been taught? I also want to know if the ability to express themselves will help students to better understand math and how they learn it.

The Principles and Standards for School Mathematics (NCTM, 2000) emphasizes the importance of communication skills. It also recommends a practice of orchestrating classroom discourse – moving from a teacher centered classroom to one that is centered on student thinking and reasoning. Traditional classrooms put the authority and talk in the hands of the teacher, leaving the students little opportunity for thinking and reasoning. By encouraging a state of cooperative learning and classroom discussion focused on student-to-student exchange, students will be encouraged to construct and evaluate their own and their classmates' knowledge and reasoning and will become better problem solvers.

This study is worth knowing for my own practice because it will help me to better monitor student learning and therefore allow me to adjust teaching strategies and the curriculum that is taught. It will help students develop better communication skills that will help them to understand and express what they are learning, as well as increase their ability to use math vocabulary. It will help them to reflect on what they understand and the steps they are taking to solve mathematical problems.

Communication skills in math, whether they be oral or written, can be helpful to the general public and the larger community of educators because it can help others to see how students process information and realize that what teachers are teaching may not always be what students are learning. It can help teachers in general to see the relationship between inquiry and knowledge and how we can use what students are having difficulty with to develop subsequent lessons and curriculum. Communication is one of the NCTM process standards and it is important to see the link between oral communication skills and the transfer to written communication and problem solving

LITERATURE REVIEW

The Principles and Standards for School Mathematics (NCTM, 2000) emphasizes the importance of communication. It also recommends a practice of orchestrating classroom discourse – moving from a teacher centered classroom to one that is centered on student thinking and reasoning. Cooperative learning and increased classroom discourse have been researched as methods to increase student communication and conceptual understanding in mathematics. Traditional teaching in math classrooms has focused on "teacher talks – students listen." Learning in this manner tends to be very passive and memory-based, making low cognition demands on learners (Bernero, 2000). Doing mathematics is a collaborative activity that depends on communication and social interaction (Hiebert et al, 1997). Learning with understanding can be (further) enhanced by classroom interactions, as students propose mathematical ideas and conjectures, learn to evaluate their own thinking and that of others, and develop mathematical reasoning skills (NCTM, 2000).

Much of the research on cooperative learning and classroom discourse has focused on the benefits gained by students. They showed growth in several areas such as confidence in using mathematical vocabulary, a general comfort with communicating orally, and a better understanding of their thought processes (Huggins & Maiste, 1999). Mulryan's (1995) research indicated that students' engagement was much greater in small groups than in whole class settings and that students were more actively engaged in the small group setting. Bernero (2000) also reported that with cooperative learning, it was observed that the social environment of the classroom became more positive. As the classroom engaged in more cooperative activities, a unity, or caring atmosphere seemed to emerge for the class and that carried through the school day, not only during math. He also reported that cooperative learning does much to foster a caring, team-like atmosphere. It definitely builds one's self-esteem and encourages even shy students to assert themselves (Bernero, 2000).

Many researchers found that cooperative learning was especially beneficial to students' reasoning and conceptual understanding. Kilpatrick (2002) stated that one of the best ways for students to improve their reasoning is to explain or justify their solutions to others. When one is able to use what they are learning by listening, speaking, doing and teaching (to their peers), the concept, or idea becomes more thoroughly understood and engrained in one's mind, whether it is math or any other subject matter (Bernero, 2000). In a study done by Chambers (1995) he quoted the words of the teacher in his project. She stated, "When kids listen to each other they understand better than when they hear directly from me (teacher). It makes more sense to them…I really see a lot of learning going on when children listen to other children." (p. 379). Through discussion and listening to others, students also find that there may be more than one way to solve a problem. If a student was unable to understand a concept or apply it in the way it was explained, his team members would explain or show it in a different way. Many times this was successful in helping the student get back on track (Bernero, 2000). Communication increases the likelihood that students will think again about their own method and hear about other methods that would work just as well or better (Hiebert et al, 1997). Huggins and Maiste

(1999) also reported from their research that children should have many opportunities to talk about and work out situations orally in groups before we expect them to write about them.

In addition to cooperative learning, classroom discourse plays a key role in students' understanding of math. Kilpatrick, Swafford and Findell (2001) in their book *Adding it Up,* state, "Research on creating classrooms that function as communities of learners has identified several important features of these classrooms…In such classrooms the teacher plays a key role as the orchestrator of the discourse students engage in about mathematical ideas" (p. 425). The classroom environment should value the contributions of students, hear all voices, maintain high expectations for all students and foster a sense of community among learners (Fagan, 2005). Of special importance in classroom discourse was the method of orchestrating the classroom discourse. Kazemi (1998) and Huggins and Maiste (1999) all studied the differences in classroom discourse. Huggins and Maiste report that classroom interactions should be focused more on the construction of meaning than on the delivery of facts. The question to the student needs to be "How did you get that answer?" rather than "What answer did you get?" Asking students to explain how they found an answer requires students to think about the language of mathematics.

Kazemi (1998) did a study of four classrooms and identified four socio-mathematical norms that guided students' mathematical activity and helped create a high press for conceptual thinking. These included: explanations consisted of mathematical arguments, not simply procedural summaries of the steps taken to solve the problem; errors offered opportunities to reconceptualize a problem and explore contradictions and alternative strategies; mathematical thinking involved understanding relations among multiple strategies; collaborative work involved individual accountability and reaching consensus through mathematical argumentation.

Wood (1999), in his research project, found that argumentation had a significant positive effect on students' conceptual understanding in math. The findings from his research indicate that creating a context for argument in classrooms requires that teachers establish expectations for children's thinking and participation while they explain their solutions to others. He noted however, that teachers also needed to establish expectations for their students as listeners.

Listening as a student is important, but it appears that the teachers also must practice the role of listening during classroom discourse. To understand the thinking of children, teachers need to spend more time listening to children describe how they think and less time explaining to the children how the teacher thinks (Chambers, 1995). It is only when students are given an opportunity to voice their thinking that teachers truly comprehend what is happening in the minds of their pupils (Shanefelter, 2004). Hearing students talk about what they understand allows the teacher to fill in the pieces that are missing from a child's understanding and thus the concept can be grasped more fully (Huggins & Maiste, 1999).

Although much research points to the fact that cooperative learning and classroom discourse appear to have positive effects on students' conceptual understanding of mathematics, there are also problems associated with these methods. NCTM (2000) states that starting in grades 3-5, students should gradually take more responsibility for participating in whole-class discussion and responding to one another directly. Wilgus (2002) did research on peer collaboration with 3rd and 4th grades. From her data, she concluded that peer collaboration was not a significant factor at the third grade level for academic achievement. Huggins and Maiste (1999) also noted that when comparing 3rd and 4th grade students and their ability to communicate the what, how and why of problem solving, 4th graders saw an improvement, but it appeared that 3rd graders needed more manipulatives and in general more concrete interventions that would allow them to see the what, how and why of problem solving. In addition, younger students need more time to learn and process concepts. Mulyran (1995) found that low achievers are less actively involved than high achievers in small groups. He also found that girls had more problems with, or perceived themselves to be having problems with, cooperative learning tasks. Bernero (2000) also cited problems associated in working with cooperative groups: control over noise level, keeping teams on tasks, and dealing with students who don't get along socially.

Teachers who use cooperative small group instruction need to become aware of the individual student's patterns of responding in small groups and take steps to promote more active involvement by all students and especially low achievers, in groups (Mulyran, 1995). He also notes a study by Corno and Mandinach (1983) that low achievers may have been more actively involved and might have cooperated more fully on tasks if students would have been given instruction in cooperative work groups. Kilpatrick and Swafford (2002) also emphasize the need for training as they state, "students in groups can work on a math task together and thereby increase their proficiency. But if the task does not allow each student to contribute and if students are not sure what they are supposed to do, precious learning time is wasted. For groups to be effective, tasks must be well chosen and students must be taught how to work in this mode" (p 27). Bernero (2000) also echoed the need to teach social skills prior to using cooperative learning in math.

Along with training students for their roles in cooperative learning, it appears to be important that teachers and students also be properly trained in the use of classroom discourse. Improving discourse in the classroom is not something that can be done without thought or effort. We cannot expect all students to come to class with the communication skills necessary for participating in class discussion and working with other students (Van Zoest & Enyart, 1998).

Nathan (2003) states that even though student led discussion increased greatly, it lacked the mathematic precision offered previously by the teachers. He goes on to say, "In short, teachers need to learn the stepping in and out that is paramount to promoting productive discourse" (p. 204). He also quotes an article written by Ball in 1993 entitled, *With an Eye on the Mathematical Horizon: Dilemma of Teaching Elementary School Mathematics.* She states, "Teachers need to continually monitor where the discourse is going and have some criteria for deciding how to know when the class has arrived" (p. 204). Nathan (2003), states that teachers and teacher educators are faced with the challenge of promoting discourse-based practices, but he also notes that this is difficult because mathematics teacher education programs have not prepared teachers for this type of instruction.

In light of the research that has been done on cooperative learning and increased classroom discourse in mathematics classroom, it appears that it has been fairly successful, but more emphasis needs to be placed on preparing both students and teachers for their roles in the use of these procedures. If these procedures are to be considered as successful strategies for helping students to better communicate and understand mathematics, then there needs to be careful monitoring of how they are being used by both teachers and students. There also needs to be evidence that these procedures are actually helping students to understand concepts of mathematics, and having a positive effect on their attitudes about problem solving and math in general.

PURPOSE STATEMENT

This study was being conducted for the purpose of determining the effect of improved classroom discourse and cooperative learning on students' ability to understand and explain mathematical concepts and problems. Data collection took place during the spring semester 2006 in the researcher's 6th grade math classroom. The study attempted to answer the following research questions:

- What effects will changes in teacher's questioning and "authority" status have on students' discourse and understanding?
- How will students' discourse and ability to explain improve after using cooperative learning?
- How will increased student discourse affect students' understanding, and use of math vocabulary and written explanations?
- What effect will increased student discourse have on students' attitudes about problem solving, and math in general?

METHOD

A variety of methods were used to collect data for this research project. All of my research questions were addressed using pre and post math interest and learning surveys (Appendix A) of all students, and pre and post interviews (Appendix B) of 6 random students whose names were drawn from a hat. Additional data collection methods included: videotaping and follow-up analysis and reflection of classroom lessons in which small and large group discussion took place, self-reflection journals by the teacher, student journals, and group work rubrics (Appendix C) filled out by students.

Specific data collection methods used for my first research question focused on videotaping of lessons involving small group work and whole classroom discussion on a weekly basis. These were later reviewed by the researcher and analyzed for the amount and types of discourse using Video Codes for Analytic and Social Scaffolding (see Appendix D). Teacher observations and reflections during class were used, along with the follow-up viewing of the videotapes to assess changes in student discourse and understanding. Student journals and responses to lesson prompts were used in conjunction with a journal rubric to observe students' thoughts and perceptions about working and learning in cooperative groups, as well as to assess student understanding of the concept being studied. Scores on Terra Nova Achievement tests given during the research time period were also compared to scores from the previous year to assess whether increased use of student discourse and cooperative learning had an effect on student understanding.

The second research question, how will students' discourse and ability to explain improve after using cooperative learning strategies, was assessed in many of the same ways as the first question. Specific items on the pre and post Math Interest and Learning Survey that addressed this research question were:

-I like to answer questions asked by the teacher in math class.
-I feel comfortable asking questions in math if I don't understand.
-I am comfortable sharing my mathematical ideas with the whole class.
-I am comfortable sharing my mathematical ideas in a small group
-I like to go to the board to present my math solutions to the whole class.

They were also asked to respond to these two open ended questions: Compared to the beginning of this project, how has your participation in small group discussions changed? How has your participation in full class discussions changed?

Questions on the pre and post interview that addressed this research question were:

-Compared to the beginning of this project, how has your comfort and confidence changed while sharing in small group work? In full group discussion?
-Have you noticed any changes in yourself or other students with regard to math

confidence after these two months of working in groups?

-After we worked and practiced cooperative group strategies, what changes did you notice in how you or other members in small groups worked and listened?

I also used teacher observations/reflections during class and of the videos to assess changes in students' ability to explain. Two sections on the student group work rubric were also used to analyze how students felt about their participation and comfort when working in small or large group discussions.

In order to assess whether increased student discourse would have any effect on students' understanding and use of vocabulary, a pre and post vocabulary survey/test (See Appendix E) was administered to all students. Teacher observations during the lesson and of follow-up videotapes were also done to monitor signs of vocabulary use. In order to assess how students felt they had used vocabulary during small and large group discussions, a section on the group work rubric allowed them to respond to their use of vocabulary. Students were asked to respond to the questions about vocabulary use in both the pre and post interviews.

The final research question attempted to see changes in students' attitudes about their ability to understand and explain mathematical solutions, as well as their attitudes about math in general. Data was gathered from the pre and post Math Interest and Learning Survey, student pre and post interviews, the group work rubric, and teacher observations of students during class and in follow-up viewing of videotapes. Items on the pre and post interest surveys that particularly addressed this question were as follows:

-I am good at math.

-I like to work in groups to do math.

-I think I learn a lot when I participate in a discussion with other students.

-Working in a group helps me to understand math better.

-Working in groups is better than listening to the teacher.

-Working in groups makes me more confused about math.

Specific questions in the student interview that addressed this research question were:

-What do you like about working in small groups and how has working in small groups helped you learn and understand math?

-Some students think they understand math better when it is explained by a student rather than the teacher. How do you feel about that?

A group work rubric, that students completed following lessons in which included either small or large group discussion, was used to collect data on students' responses to issues such as learning, understanding, participation, comfort, and use of vocabulary. The responses to the sections on Learning and Understanding were used to gather data on this research question.

ANALYSIS

Changes in the teacher's questioning and authority status resulted in improved student discourse during math classes and an apparent increase in student understanding of math concepts. It is quite evident from watching the videos that my students have become very enthusiastically and actively involved in discourse. As a teacher, I have provided them many opportunities to work in small groups, as well as full class discussions. When put into small groups, they immediately responded to the task at hand and worked together to discuss and/or find solutions. I generally put them into groups of three. I noted that in almost all video observations that I reviewed, all members in the group were involved in the discourse. In a closer observation of three particular small group situations I found that all members participated, however a count of the number of times each person contributed generally indicated a split of approximately 37%, 37% and 26%. As I analyzed the reasons why one person appeared to speak less than the other two members, three common ideas surfaced: the third person was generally not a "group" worker and never contributed in small group work; the third person wasn't confident enough with the material to contribute to the discussion, but yet appeared to be actively involved in listening; the third person was not comfortable with other members of the group. Since I chose groups randomly each time we did group work, students were generally never with the same persons. Comfort level with other members of the group appeared to play a big factor in the amount of discourse within some groups, however students never refused to work with others in the group they were assigned to.

When students worked in small groups, they were actively involved in finding solutions. This active involvement was noted by the fact that in almost all observations everyone was working the problem on a piece of notebook paper or on a white board. Many times someone in the group also had the student reference book out and was looking through it to help the group discover a solution. I observed and heard many discussion phrases such as: "How did you do it?" "I know what I did wrong now." "Let's try it this way." "I looked in the book and it says….. so I think…." "If you have questions, please ask." "That can't be." "Do you understand,___? " I also observed that students who generally didn't say much during teacher lectures and large group discussions were asking questions of their partners and offering suggestions for solutions. On at least two occasions, a student who was considered "less knowledgeable" about math, was able to explain a concept to a "more knowledgeable" student who was having difficulty understanding.

The students depended on the members of their group to help find solutions rather than expecting a solution from the teacher. Although the teacher was constantly circling the room and observing student group work, the students never asked the teacher for a solution. Occasionally they would ask if an answer was correct, or they would ask for a clarification of the problem.

I also noted that when students were in small groups, I very rarely had to remind them to "pay attention to their group" or to discipline them for distracting behaviors. In lecture or large group settings this was happening more often because of the lack of active involvement, therefore leading students to have their own side conversations or "tuning out" completely.

An interesting observation that I made was in regard to a student who did very poorly with staying on task and listening in lecture/large group discussions. When he was in a small group he was almost always on task and genuinely interested in trying to learn from his partners. The students in his group were almost always more patient with him than I was and made it a point to involve him so that he would understand. I observed that they put him in charge of drawing a solution on the white board and they also encouraged him to present the solution to the whole class on the large board. I also observed many occasions when they specifically checked for understanding with this student by asking questions such as, "Do you know why we did that" or "Can you explain that to me now?"

I experimented with putting students into small groups as a method for students to discover a math rule or concept before I explained the rule or concept in a large group lecture. For example, I did this with finding the formula for surface area of a cylinder and for discovering a rule for subtracting integers. Most of the students used outstanding discussion and trial and error methods to check out their solutions. They were excited and pleased with themselves when they could figure out a solution that really worked. I observed numerous occasions when they celebrated their success with a high five or a shout of acclamation that they found the solution.

I also experimented with discovering a math rule or concept, and with discussing it once it was discovered in large full class discussions. When I used large class discussions I wanted to relinquish my role as "the authority," so I purposely didn't stand at the front of the room, but rather stood at the side and tried to limit my discourse to questions rather than stating math rules or principles. My intent was to get the students to discuss more among themselves rather than being dependent on me. I used the “Video Codes for Analytic and Social Scaffolding” (Appendix D) to monitor the discourse in the classroom. On three occasions when I made a deliberate attempt to relinquish my role as authority, I video recorded and then analyzed the results. What I found was that the Teacher to Student and Teacher to Class discourse was half of less than the amount of Student to Student and Student to Teacher Discourse. That was especially pleasing to me because it indicated that I was actually getting the students to discuss more. I also noted that when I specifically compared the Student to Student and Student to Teacher Discourse, students were twice as likely to have discourse with each other than they were to have discourse with the teacher. Once again, I was pleased to see those results as it indicated to me that students actually were becoming more involved in their learning. I also noticed that the student to student discourse increased more as the study period progressed. They had become comfortable with the thought of discussion and now weren’t afraid to question one another. While the video codes helped me to see that student discourse was increasing, I also made another observation. It appears that it tends to be the same students who do most of the talking in large group discussions, while other students still remain quiet and don’t get involved. It was this observation, combined with student journal notes and interviews, that led me to the conclusion that large group discussions with the teachers relinquishing the authority role leads to increased classroom discourse, but it may not lead to greater understanding for all students. The students had these comments about using the full class format: “There were too many people talking and too many ideas shared, so it was confusing.” Other students stated, “It was good to have so many ideas and discussion because then we understand more because there were more ideas to draw from." My observation was that students who liked the full class discussions/debates were those who had a better understanding of math in general, so they could sort out the ideas on their own. The students who struggle more with math were very confused by too much discourse in large groups and therefore preferred just a few ideas from a small group.

A final student survey/journal indicated a preference for small group discussions over large group by a ratio of 10 to 1. Further evidence indicating that less teacher authority results in more discourse and understanding can be found in the student responses to post interview questions, responses to the interest and learning survey, and group work rubrics. These results will be shared more conclusively in the analysis of question four.

Scores on Terra Nova Achievement tests were also analyzed to check for changes in students understanding as a result of increased discourse. Normal curve equivalencies of individual students were compared for the specific test on mathematics. Of the 15 students who took both tests, 12 had scores that increased, 2 students had a score that decreased, and 1 student remained the same. After excluding one student's score, which increased by 40 points (probably due to being a new student shortly before the test was administered last year), the average student increase for normal curve equivalent was 7.09. The class NCE increased from 62 to 78. The NCE scores show an increase from where the students were last year, which could indicate increased understanding, but these same students had seen a similar increase the year before. Therefore, it cannot be clearly determined from these test scores alone that increased discourse leads to better understanding. It could be that the curriculum is sufficiently covering the concepts on the test in order to show progress from year to year despite the method of delivery.

Although much of the evidence suggests that less teacher authority increases student discourse, it is not clearly evident that it improves student understanding. Exit interviews were done with six randomly selected students. They were asked to respond to this question: "Some students think they understand math better when it is explained by a student rather than by the teacher. How do you feel about that?" Four of the 6 students said it was better when the teacher explained. One student said they preferred students because they use "kid terms." One student said it was the same whether student or teacher.

The second research question addressed the issue of whether student discourse and ability to explain would improve after using cooperative learning strategies. My assertion is that cooperative learning strategies will improve student discourse and help them feel more comfortable when working in groups. My 6th grade class was fairly comfortable with the idea of using small group work because I have used it often in math as well as other classes that I teach. After I received Institutional Review Board approval, I then took a few days to practice cooperative learning strategies as discussed in E. G. Cohen's book entitled *Designing Group Work: Strategies for the Heterogeneous Classroom.* We first did the "5 square problem" to help them see the importance of being aware of the needs of others. As I observed their interactions in this activity, I noted that students who are better at cooperative learning in math were also the ones who were better at working on the problem solution in this situation. Students who tended to be more self centered, reluctant to seeing the needs of others, or resistant to following instructions in this activity, were also students who exhibited these same behaviors in classroom group work. We discussed this and shared similarities of the "5 square problem" to working in math small groups. Some of the connections they found were:

> We had to find a solution and there was more than one solution.
> When I got it I felt good, but I wanted others to get it too.

Some people didn't know the language (square, congruent) so it hindered our efforts.
It takes people to be aware of what is going on.
We had to find new ways to do things.
I felt stupid being the last one to get it.
I was upset with __, because he didn't listen and do it right so it affected our whole group
I felt confused; we needed more time.
It's like being under pressure to solve a math problem.
We had to work together to get a solution. It was challenging.
You need to know when someone needs help and help them when they are stuck

They could really see the relationship to some of the things we've done in math, but I'm not sure if they were continually reminded of these things as they continued to work in math groups.

We also practiced a reflective listening activity. This was a much harder concept for them because this age group tends to be very self-centered and they have a hard time listening. The process itself involved 4 steps:

Consciousness - each person talks for only 15 seconds
Listening - each talks only 15 seconds, but wait 3 seconds before the next person talks
Reflecting - first person talks, wait 3 seconds, 2nd person must repeat what first person said before stating anything new.
Everyone Contributes - each person had to talk before anyone talked a second time

We first applied this process to non-math type situations, and then we tried it with a math problem. It was interesting to see how they struggled with this. Two of the hardest steps of this process were: make sure everyone in the group talks and reflecting the ideas of the person who spoke before you. Many students admitted that they didn't reflect because they weren't really listening to the person ahead of them. Instead they were trying to come up with their own idea of what to say. The first day we did this process their responses in their journals were full of frustration. Some of their comments were as follows: "Reflecting was hard because some people didn't list or didn't understand what was being said." "We all got mad because we couldn't get the answer." "Why do we have to reflect when we all get the answers?" "I was mad at the whole group because everybody was talking at the same time and nobody would listen to me." "The second problem was even more frustrating because two of us came up with a lot of answers and not everyone was talking so nobody really shared any ideas." "We didn't really reflect." "I hardly understood what the people in my group said and did." "I listened to my group but most of the time didn't understand what they were saying because we didn't take 3 seconds and I got confused by that." "We didn't really do the 4 things on the board, we were either out of it or too into the problem." I believe the frustration was two-fold: the math problems we used were more difficult and not related to the concept we were studying at the time. Secondly, they were not comfortable with the process.

Two days later I had them journal about group work involving this process. Their journals were much more optimistic with comments such as: "Our group did poor reflection, but we did good listening and questioning and we all showed the person how to figure out a problem they didn't understanding." "I asked many questions because I didn't really understand, but we did not reflect because it took too much time." "In my group we didn't do much reflecting but we did some. We all had questions and we listened how we got that answer. We all shared by telling how we got it." "In our group we used listening and questioning. We did not use reflecting that much but we shared our answers. If somebody had the wrong answer they told us what they did and then the others said how they got it." They described how they took turns talking and asking questions of each other. Most admitted that they did not use the reflection step. Some said they didn't because it takes too much time. Overall, students just seemed more positive with the process and used better cooperative strategies. Due to time constraints and a curriculum to get through, I did not take any more direct time to teach and practice cooperative strategies like those presented by Cohen. However, I occasionally reminded them to use the 4 steps. My observations of the videos indicate that students are using these strategies quite well in small group discussions. They are listening to one another, rephrasing and ask questions. This is not happening in large group discussions. In fact, large group discussions often get out of control with too many students trying to talk at the same time and not much reflecting or rephrasing.

One of the aspects of student discourse that I have focused on is whether students feel that they learn and understand better in each of these three settings: teacher led lecture/demonstration, full class discussion, or small group discussion. As I've collected this data over a course of about four weeks I've noticed a change in student responses to this question. Initially I had 3-4 out of 17 students who definitely indicated that they preferred teacher led lectures over group work. Over the course of the project, two of those students made a definite change to preferring small group work as their preferred method. I also observed that these two students have shown a more confident role in student groups and are more willing to share ideas. One of them has even taken on a more active/leader role when in a group. I also noted that one student went in another direction. His responses started to indicate that he would just rather learn on his own. I've also observed that this student does not function well in small group work in math, and he also has difficulty with getting along with students in general, whether it be in other classes or on the playground. However, I did observe that this student is one who is very willing to answer questions in large group discussions and he is also one of the first students to volunteer to go to the board to share his answers/methods. He seems to have a good understanding of math, but does not do well with sharing that understanding with others.

In order to know whether students' perceptions of their discourse and ability to explain improved, I included some questions on the interest surveys and interviews. One of the survey questions was: "Compared to the beginning of this project, how has your participation in small group discussions changed?"   No answer choices were given.   Students just wrote in a response.

This is a summary of what was said:

I talk more - 7
I understand more - 2
I listen and reflect more
No change - 3
If I know it, I help others
We work together more

The same question was asked about participation in full class discussion. Responses were:

I participate more - 3
I understand and pay attention more - 2
I am not afraid to risk giving an answer, even if it is wrong
I am less shy
I am more comfortable
It's easier, I'm used to it
No change
I never talk, so no change

Questions on the "pre and post interest survey" and mean of each:

	Strongly Agree 5	**Agree 4**	**No Opinion 3**	**Disagree 2**	**Strongly Disagree 1**	**Pre Mean**	**Post Mean**
I like to answer questions asked by the teacher in math class.						2.8	3.47
I feel comfortable asking questions in math if I don't understand something.						3.375	3
I am comfortable sharing my mathematical ideas with the whole class.						3.18	3.58
I am comfortable sharing my mathematical ideas in a small group.						3.8	4.23
I like to go to the board to present my math solutions to the whole class.						3.18	2.47

What I noticed in this collection of data, was that students seemed to become more comfortable with sharing their mathematical ideas in the whole class and small groups as indicated by the increased mean score in these three questions:

I like to answer questions asked by the teacher in math class
I am comfortable sharing my mathematical ideas with the whole class

I am comfortable sharing my mathematical ideas in a small group

This correlates to what they indicated in the open response questions. Students appear to be less comfortable with behaviors that would expose their lack of knowledge about the subject and/or cause them embarrassment. For example, the mean scores on these two questions decreased:

I feel comfortable asking questions in math if I don't understand
I like to go to the board to present my math solutions to the whole class

Two sections on the group work rubric that addressed this question are included in the table.

	1 point	2 points	3 points
Participation __________ score	• I feel like I didn't participate very much and could have contributed more ideas than what I did.	• I feel like I participated a moderate amount and contributed some ideas to the discussion.	• I feel like I participated a lot and contributed many ideas to the discussion.
Comfort __________ score	• I didn't feel very comfortable participating in today's lesson/activity.	• I felt somewhat comfortable participating in today's lesson/activity.	• I felt very comfortable participating in today's lesson/activity.

The class average scoring results were as follows:

	Small Group	Large Group	Combination of Small and Large Group
Comfort	2.51	2.43	2.47
Participation	2.4	1.93	2.26

As this indicates, students participate more and feel more comfortable when they are in small groups as compared to large groups.

I also addressed this research question (how will students' discourse and ability to explain improve…..) through questioning in the exit interview of the same six random students whom I interviewed at the beginning of the study. Questions and summary of responses are listed below:

- Compared to the beginning of this project, how has your comfort and confidence changed while sharing in small group work?
  -I pay attention more

-As we go over it more I'm more confident to explain my ideas
-we do it so many times, it has become natural
-I'm not so shy
-I don't like to share ideas
-It's the same

- Compared to the beginning of this project how has your comfort and confidence changed while sharing in full group discussion?
  -I am still scared to talk in large group
  -I don't like it when everyone sees you get it wrong
  -I am more comfortable to go to the board
  -better
  -it's a chance to talk, so I just say an answer
  -I don't know

- Have you noticed any changes in yourself or other students with regard to math confidence after these 2 months of working in groups?
  -some are less shy, stubborn
  -some kids who never really talked, follow more
  -when we go over it, they understand it and then are more confident to show others
  -yes, more people talk
  -not really -2

- After we learned and practiced cooperative group strategies, what changes did you notice in how you or other members in small groups worked and listened?
  -we listened to each other and listened if someone wasn't getting it
  -we talked more and understood it more
  -we learned reflecting, so we think of what was said instead of blowing past it
  -it made it less confusing and gave others a chance to talk
  -reflecting was hard if you weren't listening
  -we didn't repeat/reflect like we were supposed to

These responses also correlate to the other evidence that indicates that working in groups has helped students to improve their discourse and ability to explain. They appear to notice that other students are talking more and displaying more confidence. They also noticed that they need to listen more to the other students, but also found it difficult to actually use the "reflection" step.

The analysis of how increased student discourse would affect students' understanding and use of vocabulary and written explanations was not very conclusive. Pre and post vocabulary survey/tests (See Appendix E) were used to indicate a change. Students were to mark each word with a score of 1 – 4 as follows: If they gave it a 3 or 4, they were to define the word.

1 – Never heard or seen this word
2 – I've heard or seen it, but don't have a clue of what it means
3 – I've heard of it, but I'm not exactly sure what it means. I'll make a guess.
4 – I'm pretty certain that I know what it means and can define it.

It was discovered that this device may not have been a good indicator. It appears that the specific vocabulary words being used and studied at the time that each particular survey was administered were given a 3 or 4 by the majority of the students. During the pre-survey we were studying angles and triangles so the words associated with these concepts received higher scores, while the vocabulary being studied at the time of the post survey was related more to integers and algebraic equations so students scored better on these words in the post survey/test. It is assumed that over the course of the seven weeks of the study students were introduced to many words that they hadn't been exposed to or hadn't used in more than a year. Therefore, it is not clearly evident that the use of increased classroom discourse led to the increased knowledge and use of vocabulary, or whether it was just a matter of recently being exposed to the terminology.

Teacher observations initially indicated that students were developing the ability and confidence to use correct math terminology. On one particular occasion a student very distinctly gave an explanation using newly-acquired math vocabulary and you could see the beam of pride in his face as he knew he had used correct terminology. However, as the study period progressed it was observed that the students who struggle with vocabulary in all subjects are also the ones who struggle with using vocabulary in math, while the students who are fluent in vocabulary in all subjects also tended to use and understand it more when asked to explain orally or give a written response.

Students' perception of vocabulary use was addressed in the vocabulary section of the group work rubric. After lessons in which small or large group discussion was utilized, students were to rate themselves on a score of 1 to 3 with relation to how they used vocabulary in their groups. A score of 1 indicated they didn't feel they used much vocabulary and 3 indicated that they used many math words appropriately. This type of data was collected from students on 5 different occasions. The average score of those five occasions was 1.64, with a high score of 1.80 and a low score of 1.31. This indicates to me that students do not feel very strongly that they are increasing their understanding and use of math vocabulary. One factor to bear in mind is that some math lessons lend themselves more to the use of math vocabulary than others, and the particular lessons being studied on these days did not have a significant amount of vocabulary.

Students' perceptions of the use of math vocabulary were also gathered in the pre and post interviews. In the pre interview students were asked, "Do you use math vocabulary words when you explain answers or give reasons?" Almost all of the students indicated that they did use vocabulary, but seemed unable to name more than just a few examples of math vocabulary words. In the post interview students were asked, "After working in small and large group discussions, what changes have you noticed in you or your classmates' abilities to use math vocabulary?"

Two of the six students interviewed indicated that they didn't really see any change in vocabulary use, two were somewhat neutral in their response, and two indicated that they felt vocabulary words were used more often. None of the students who were interviewed gave specific examples of vocabulary that had been used.

The student survey was also used to collect data about changes in students' ability to write about math. The results displayed in the chart below do not indicate that students perceived increased discourse to have improved their ability to explain through writing.

	Strongly Agree 5	**Agree 4**	**No Opinion 3**	**Disagree 2**	**Strongly Disagree**	**Pre Survey Mean**	**Post Survey Mean**
It is easy for me to write about my reasoning and how I solved a math problem.						2.9	2.82
Working in a group and discussing math ideas helps me to write about my solutions.						3.56	3.11
Writing about math concepts and problem solving after we have discussed them helps give me a better understanding of what we just learned.						3.375	3.47

The data results with regard to my final question, the effect of discourse on students' attitudes about their ability to understand and explain mathematical solutions as well as their attitudes about math in general, generally indicated a positive change. In the post interviews students were asked: "What do you like about working in small groups and how has working in small groups helped you learn and understand math?" All 6 students indicated that working in groups helped them learn it better. Some of their comments were:

It's less confusing and less boring
You learn it better
Other persons can teach you. Everybody gives ideas to help you find the right answer
More ideas and so you understand it
You hear yourself thinking
Going over it a 2nd time gives a 2nd time to learn it and it stays in my mind better
It's explained in a "kid way"
I understand how to get the problem – the process

I also used a group work rubric with questions about how group work helped them to learn and understand better. These rubrics were handed out after we had done work in either small or large groups or a combination of small and large group. I've copied in that portion of the rubric here:

	1 point	2 points	3 points

Learning __________ score	• I don't think the discussion that took place today really help me learn any more about the subject being studied.	• I think the discussion that took place today sort of helped me learn more about the subject being studied.	• I think the discussion that took place today really helped me learn more about the subject being studied.
Understanding __________ score	• I don't think being a part of today's discussion furthered my understanding of the subject.	• I think being a part of today's discussion somewhat helped me understand the subject being studied.	• I think being a part of today's discussion really helped me understand the subject more.

The class average scoring results was as follows:

	Small Group	Large Group	Combination of Small and Large
Learning	2.28	2.5	2.29
Understanding	2.24	2.38	2.23

Although this data indicates that group work led to more learning and understanding than not, it may be difficult to prove which type of group leads to more learning and understanding because of the differences in topics studied each day and student comfort with the topic at hand. Another measure of students' attitudes about their ability to understand and explain may be indicated by their responses to questions in the exit "Math Interest and Learning Survey." A portion of the items with the before and after means are listed:

	Strongly Agree 5	**Agree 4**	**No Opinion 3**	**Disagree 2**	**Strongly Disagree 1**	**Pre survey Mean**	**Post Survey Mean**
I like to work in groups to do math.						4.4	4.75
I think I learn a lot when I participate in a discussion with other students.						3.3	3.7

Working in a group helps me to understand math better.						3.8	4.05
Working in groups is better than listening to the teacher.						2.9	3.41
Working in groups makes me more confused about math.						1.9	2.11

Looking at the mean scores of the pre and post survey, it would appear that students feel more positive about working in groups and also feel that they learn and understand better when working in a group.

A final question that students were asked to respond to in their journal as a closure to this project was: "Would you rather that we continue to do group work or prefer that the teacher lead most of the learning in class and why?" Fourteen of the seventeen students responded that they would prefer to learn in groups. Two said they preferred the teacher and one student had no preference. Some of their reasons cited for preferring groups included:

-More understanding - 6
-More fun – 2
-You use your brain more
-We learn it better
-We figure it out by ourselves
-When the teacher leads I get bored and blank out/don't listen

Changes in students' general attitude about themselves as a math student showed no significant change. This was evident in two questions on the pre and post interest and learning survey as shown in the following chart:

	Strongly Agree	**Agree**	**No Opinion**	**Disagree**	**Strongly Disagree**	**Pre Survey Mean**	**Post Survey Mean**
I am good at math						3.75	3.81

Students were asked to circle the word that best described themselves on this question:

Which of these describe you as a math student?

Struggling	OK	Pretty good	Really good
Pre - 2 Post - 2	Pre - 4 Post – 6	Pre - 7 Post – 7	Pre - 3 Post – 2

As you can see there was very little change in students' attitudes. This may be due to the fact that a study as brief as this one has not allowed ample time to see any changes that might occur if it had been done over a longer period of time.

Interpretation

Students like to learn from one another, but they still want the teacher there to serve as the final authority and foundation. They need to have student discourse in order to repeat what was learned from the teacher and to have it "stick in their mind" better. Student discourse allows students to explain concepts to one another in "kid language" or "layman terms," but they also need to be reminded and encouraged to use correct math terminology. Students prefer to work in small groups over large, full class groups because they feel safer about sharing their ideas. They also feel that there is often too much discourse in large group discussion and this can lead to confusion and chaos. As students work more in groups they become better and more confident in their ability to discuss and explain. However, they must be taught and reminded to use cooperative learning strategies so that the group discussions remain controlled and involve all participants in both speaking and listening. Most students understand concepts better after discussing them in small and large groups and therefore perform better on oral and written assessments.

As a result of my findings in this action research project I plan to continue to use cooperative learning groups within my math classrooms. I will continue to serve as the foundation figure in order to explain concepts and keep students on the right track, but I will allow them to use cooperative learning and discovery as methods of learning more often than the traditional teacher lecture/student listen scenario. I will give them ample opportunity to discuss with their classmates in order to discover, explain, question, and present ideas in order to cement newly learned math concepts in their mind. Cooperative learning strategies will be taught and practiced regularly in order that all students feel that they are contributing and involved members of cooperative learning groups. Students will be encouraged to use correct math terminology in addition to their "kid language" as they discuss and present. In addition to oral discourse as a method for improving understanding, I will also focus on using more writing to help students with their understanding. Although it was not clearly evident in my research that student writing increased understanding, I feel that I may not have done enough data collection to sufficiently prove this fact. Other research studies have indicated that reflective writing does have a positive impact on student understanding.

Getting students actively involved in their learning in order to help them understand more has been a key focus of my action research project. In order to get them actively involved in their learning, I must remember that a teacher who constantly serves as the "authority" figure and monopolizes the discussion during the lesson is only serving as an enemy in the battle to help students explain, understand, and become self-directed learners.

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(Appendix A)

Math Interest and Learning Survey
Date _______________

Rank the best way for you to learn math and problem solving. 1 is the best way and 5 is the worst way.

_____ Practicing on white boards

_____ Teacher explanations in class

_____ Reading how to do it in the reference book

_____ Having a classmate or another person explain it to me outside of class time

_____ Working in pairs or groups during class time

Mark each of the statements in the box that best describes how you feel.

	Strongly Agree	**Agree**	**No Opinion**	**Disagree**	**Strongly Disagree**
I am good at math					
I like to answer questions asked by the teacher in math class.					
I feel comfortable asking questions in math if I don't understand something.					
I am comfortable sharing my mathematical ideas with the whole class.					
I am comfortable sharing my mathematical ideas in a small group.					
I like to work in groups to do math.					
I think I learn a lot when I participate in a discussion with other students.					
Working in a group helps me to understand math better.					
Working in groups is better than listening to the teacher.					
Working in groups makes me more confused about math.					

(Appendix A) cont.

	Strongly Agree	**Agree**	**No Opinion**	**Disagree**	**Strongly Disagree**
I would rather solve problems on my own in math.					
It is easy for me to write about my reasoning and how I solved a math problem.					
Working in a group and discussing math ideas helps me to write about my solutions.					
Writing about math concepts and problem solving after we have discussed them helps give me a better understanding of what we just learned.					
I like to go to the board to present my math solutions to the whole class.					
What I learn in math never seems to stick. Even after I get a good grade on it, I still don't think I know it.					

Circle your answer.

1. Which of these would best describe you as a math student?

Struggling **OK** **Pretty good** **Really good**

2. How often are you asked to explain in writing the way you found an answer to a math problem?

Never **Less than half the time** **More than half the time** **Almost always**

3. How often are you asked to explain aloud the way you found answer to a math problem?

Never **Less than half the time** **More than half the time** **Almost always**

4. How easy is it for you to explain how you solved a math problem?

Very Hard **Hard** **OK** **Easy** **Very Easy**

(Appendix B)

Pre-Project Interview Questions

1. What do you like about working in groups during Math class?

2. What makes working in a math group difficult or not fun?

3. How many people do you think should be in a math discussion group? Why?

4. What method would you prefer that the teacher use when putting students into a math group? (choose a partner, random, teacher choose)

   Why do you prefer this method?

5. Which students do most of the discussing (asking and answer questions) during math class when we have whole group discussions led by the teacher?

   Why do you think these are the people that talk the most?

6. Who doesn't answer or discuss much when we have whole group discussions led by the teacher?

   Why do you think that is?

7. When you do group work and check answers (such as workbook pages), what do you do when you and your partner have different answers? How do you decide who is correct?

8. Do you like to answer questions asked by the teacher when we have whole class discussions?

   Why or why not?

9. When you don't understand something that we are discussing or learning in math class, do you ask questions to help you understand it better?

   Why or why not?

   Who do you ask? - teacher, parent, another student?

10. How do you know if other students are listening to you when you give answers or ask questions in large group math discussions?

11. How do you know if your partner(s) are listening to you when you are working in a small group?

(Appendix B) cont.

12. Are you willing to go to the board and explain/share your answer with the whole group? Why or why not?

13. Do you use math vocabulary words when you explain answers or give reasons? Why or why not?

14. What do you think about writing out how you solved a problem or writing about what you did wrong when you solved a problem?

14. What (if anything) makes learning and doing math fun?

15. What makes math not so fun and frustrating?

16. What can your teacher do during class to help you understand math better?

17. Is there anything that would help to make working in small groups better for you?

18. Is there anything that would help to make interacting (both talking and listening) in whole class discussions better for you?

(**Appendix B) cont.**

Post Project Interview Questions

1. What do you like about working in small groups during math class?

2. What makes working in small groups difficult or not fun?

3. How has talking about math and sharing ideas with your classmates helped you learn and understand math?

4. Compared to the beginning of this project, how has your comfort and confidence changed with regard to sharing math ideas and participating in small group work?

5. Compared to the beginning of this project, how has your comfort and confidence changed with regard to sharing math ideas and participating in full class discussion.?

6. What changes did you notice in how small groups worked, after we learned and practiced cooperative group strategies (4 step process of limit time of one speaker, pause time between speakers, reflect back, everyone contributes)

7. What are some math concepts or strategies that you understood better after working on it in a small group?

8. What are some math concepts or strategies that you became more confused about when working in a small group?

9. What changes have you noticed in your or your classmates abilities to use math vocabulary after working in small and large group discussions?

10. What effect does the make up of your group have on your ability to work in a group? (i.e. are there some people who make small group work better for you)

11. Has working in groups helped you to see that there is more than one way to solve a problem? Explain.

12. How do you feel that discussing math concepts in class and groups has helped you to write about and explain what you are learning in math?

13. Have you noticed any changes in yourself or other students with regard to their math math confidence after these 2 months of working in small or large groups?

15. Some students think they understand math better when it is explained by a student rather than by the teacher. How do you feel about that?

16. Overall, what was good or bad about being part of this project to see the effects of group work on student learning?

(Appendix C)

Group Work Rubric

Date:___________________ Lesson: _______________________

Most of today's discussion took place in a (circle one): large group / small group.
Using the criteria provided, rate yourself using a score of 1, 2, or 3 in each of the five categories.

	1 point	2 points	3 points
Participation ___________ **score**	• I feel like I didn't participate very much and could have contributed more ideas than what I did.	• I feel like I participated a moderate amount and contributed some ideas to the discussion.	• I feel like I participated a lot and contributed many ideas to the discussion.
Vocabulary & Terminology ___________ **score**	• I think that I didn't use very many math words or terminology appropriately.	• I think I used some math words and terminology appropriately.	• I think I used many math words and terminology appropriately.
Comfort ___________ **score**	• I didn't feel very comfortable participating in today's lesson/activity.	• I felt somewhat comfortable participating in today's lesson/activity.	• I felt very comfortable participating in today's lesson/activity.
Learning ___________ **score**	• I don't think the discussion that took place today really help me learn any more about the subject being studied.	• I think the discussion that took place today sort of helped me learn more about the subject being studied.	• I think the discussion that took place today really helped me learn more about the subject being studied.
Understanding ___________ **score**	• I don't think being a part of today's discussion furthered my understanding of the subject.	• I think being a part of today's discussion somewhat helped me understand the subject being studied.	• I think being a part of today's discussion really helped me understand the subject more.

*Permission granted from Lindsey Thompson to adapt and use this rubric which was originally developed by her.

(Appendix D)

Video Codes for Analytic and Social Scaffolding

This scale will be used to monitor the discourse within the classroom from teacher to student, teacher to class, student to teacher, and student to student. It will also be used to keep track of whether the discourse was analytic or social in nature.

Code	Scaffolding	Description
TS		**Teacher to student (Vertical flow of information)**
qm	A	Ask question – Math
rm	A	Response to math questions from student
qn	S	Ask question – Non math
mg	S	Management – discipline, admin. homework
x	A & S	Other
TC		**Teacher to class (Vertical flow of information)**
om	A	Open invitation – Math question, challenge, yes-no
dm	A	Declaration of math principle, fact, rule
mg	S	Management – discipline, admin, homework
x	A & S	Other
ST		**Student to Teacher (Vertical flow of information)**
rm	A	Response to open invitation – Math
dm	A	Declaration of math principle, fact, rule
rg	A	Response to management – Math
qm	A	Ask question – Math
qn	S	Ask question – Other (break time, homework)
x	A & S	Other
SS		**Student to Student/Class (Horizontal flow of information)**
pm	A	Make presentation to the class – Math
qs	A	Ask question to student – Math
qn	S	Ask question to student – Other
dm	A	Declaration of math principle, fact, rule
rm	A	Response to question/comment from student – Math
om	A	Open invitation – Math
mg	S	Management – discipline
x	A & S	Other

*Adapted from Table 1 – Video Codes for Analytic and Social Scaffolding in article entitled "Whole Classroom Discourse" by Nathan and Knuth as published in *Cognition and Instruction*, Vol. 21, Issue 2

(Appendix E)

6th Grade Math Vocabulary Knowledge

Name ______________________ Date ___________________

Below are listed are variety of math vocabulary words. Some of these words you have heard before, some you may never have heard before. Use the following numbers to identify your association with the word. Then make an attempt to write the definitions of the words that you labeled with a 3 or a 4.

1 – Never heard or seen this word
2 – I've heard or seen it, but don't have a clue of what it means
3 – I've heard of it, but I'm not exactly sure what it means. I'll make a guess.
4 – I'm pretty certain that I now what it means and I can define it.

_____ 1. congruent –

_____ 2. polygon –

_____ 3. parallel –

_____ 4. perpendicular –

_____ 5. vertical angles –

_____ 6. adjacent angles –

_____ 7. quadrilateral –

_____ 8. vertex –

_____ 9. supplementary angles –

_____ 10. trapezoid –

_____ 11. sum –

_____ 12. equation –

_____ 13. variable –

_____ 14. product –

_____ 15. integer –

_____ 16. factor –

_____ 17. expression –

_____ 18. absolute value –

_____ 19. integer –

_____ 20. base –

_____ 21. exponent –

_____ 22. whole number –

______ 23. perimeter –

______ 24. volume –

______ 25. radius –

______ 26. proportion –

______ 27. circumference –

______ 28. square number –

______ 29. rational number –

______ 30. area –

______ 31. commutative property –

______ 32. diameter –

______ 33. pi –

______ 34. associative property –

______ 35. ratio -

______ 35. square root –

______ 36. surface area –

______ 37. distributive property –

______ 38. order or operations –

______ 39. reciprocal –

______ 40. prime number -