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Jessica Haley Thompson
Mankato, KS

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Jessica Haley Thompson
Mankato, KS

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Enhancing Problem Solving Through Math Clubs

Abstract

This action research paper was about a mandatory math club of seventh graders that met once per week over a 12-week period. The students gathered in the classroom during their regularly scheduled math class. The focus of the math club was to solve challenging math problems, usually cooperatively, and sometimes competitively. The math club activities varied from week to week to offer an element of surprise. Frequently, the students presented their solutions to peers, along with an explanation of the way they solved the problem. Instruments were used to collect information about problem-solving accuracy, student attitudes, and student and teacher behaviors. I discovered a slight improvement in problem solving. Also, on Math Club days, the teaching was less teacher-centered and more student-centered. As a result of this research, I plan to offer my middle school students more problem-solving opportunities and I plan to allow my students to work cooperatively on a regular basis.

This study is about incorporating a math club into a seventh grade classroom. The study sought to determine the impact of the club on student problem-solving skills. Changes in student and teacher behaviors also were examined. Attitudes toward problem solving and cooperative learning were monitored.

This topic was selected after members of the fourth cohort of the Math in the Middle Partnership described some of their experiences with their own math clubs. After reading an article by Papanastasiou and Bottiger (2004) that described a middle school math club in Kansas City, I was even more intrigued about ways a math club could improve student learning.

A large portion of the mandatory textbook for my seventh grade math class was about computation and algorithms, and consequently, I found that problem solving got pushed aside in my teaching. I wanted to investigate the effect of a repeated, enjoyable "club" atmosphere for doing problem solving. I wanted to see what happened when students were given multiple opportunities to solve problems for fun. I hypothesized that the students would be better at solving problems after 12 weeks of this treatment.

The biggest problem in my classroom is that many of my students are hesitant to set up problems on their own. These can be word problems that are applications that fit with the current lesson from the textbook or word problems with unfamiliar types of problem solving. Sometimes it takes very little, such as encouraging students to get some words or numbers on their papers, to get students to start working on these problems. Sometimes it takes quite a bit of time and effort to help them get a foothold on the problem. Just like anything, problem solving takes practice, and with practice they usually get better. My concern is that usually they do not see these problems as fun.

I am not a person who thinks everything needs to be entertaining for students, but I think enjoying math, at least part of the time, is important and facilitates learning. The majority of the content in the mandatory textbook for my seventh grade math class is neither too easy nor too difficult for most of my students. Having content that is at an appropriate level is conducive to happy students. With some of the difficult problem solving in the text, students can sometimes become frustrated or overwhelmed and do not do their best. Having a fun atmosphere lets the students know that regardless of the difficulty of the problem, everyone in the room will support each other and enjoy the task at hand. Students who are having fun are usually more engaged and are less likely to let their minds drift.

I also know that it is common for me to devote quite a bit of time and attention to my middle or weaker students, while not challenging my strongest students enough. Problem solving is a way to offer challenges to my top students, yet at the same time, meet my lower students. When my students have done some creative problem solving, I have been surprised to see unexpected individuals rise to the occasion. These students are usually very innovative, and they do a great job of explaining their unique approaches to the other students.

I wanted to find a way to incorporate more problem solving. I did not just want the word problems that fit into the lesson my students were doing on a particular day. Those are excellent applications, but I wanted students to work on unfamiliar problems that require a variety of strategies and creative thinking. My goal was to not have students slow down or give up every time they saw a word problem or were expected do problem solving. I wanted them to feel encouraged and supported enough to try the problem. I wanted them to feel excited about being challenged.

In my own classroom, I wanted to improve problem-solving abilities by helping students change their beliefs about problem solving and by giving students more opportunities to solve some interesting problems. This was important to my classroom because I believe I pushed the students this year to use all of their classroom minutes to learn the concepts at hand. Math club was a time to motivate and reward my students. I thought allowing them to interact with one another as they explored some unusual problems would brighten their outlook. It could renew their enthusiasm for problem solving and for math in general.

Problem Statement

Problem solving is one of the National Council of Teachers of Mathematics' (NCTM) process standards. “Problem solving is central to inquiry and application and should be interwoven throughout the mathematics curriculum to provide a context for learning and applying mathematical ideas” (NCTM, 2000, p. 256). One of the jobs of educators is to help students to develop persistence in problem solving. Solving problems that require students to stretch their minds can lead to frustration on the part of the student. By solving problems with increasing difficulty, students improve their problem-solving abilities. Students who are determined and who have developed perseverance are more likely to solve problems than students who simply give up (NCTM, 2000).

Attitudes are also important. Research done by Kroll and Miller (1993) proposed that student beliefs about problem solving, about themselves as problem-solvers, and ways to approach problem solving can be the decisive factors in regard to success in problem solving. Believing that problem solving is fun and doable could help many students solve problems that they previously would not attempt.

In the public realm, it is important for students to be able to solve problems in a variety of contexts. In life everyone is confronted with unfamiliar circumstances or dilemmas, many of which deal with numbers. Having creativeness and a willing attitude can help a person form solutions. In any math course, students are asked to solve problems. Building problem-solving skills in my seventh and eighth grades will help students with all of their subsequent math courses and improve their analytical thinking.

Review of the Literature

This section contains a description of problem solving. More specifically, it examines some of the aspects related to a repeated, enjoyable “math club” atmosphere when doing problem solving. It looks at the research themes of types of problem solving, cooperative learning strategies, student beliefs, and classroom discourse.

Types of Problem Solving

Problem solving is defined by Schoenfeld as “a task (a) in which the student is interested and engaged and for which he wishes to obtain a resolution, and (b) for which the student does not have a readily accessible mathematical means by which to achieve that resolution” (Schoenfeld, 1989 as cited in Bottge, 2004, p. 81). Some of the challenges for students in problem solving are poor reading comprehension, lack of confidence in their ability to solve problems, lack of interest in the problem at hand, and little experience solving non-routine problems (Bottge, 2004).

Providing students with direct instruction on specific problem-solving strategies such as make a diagram, guess and check, consider a simpler case, and look for patterns has benefited some students. Higgens (1997) compared three classes of middle school students who received five weeks of direct instruction on problem-solving strategies with three other classes that received more traditional instruction. Additionally, the students experiencing problem-solving strategy instruction were given weekly challenge problems for the remainder of the year following the initial five-week strategy instruction. Each weekly challenge problem had no obvious way to arrive at a solution and was geared toward the interests of sixth and seventh graders. Throughout the week, these students would share their strategies for the problem with one another. Problems requiring laboratory work, manipulatives, cooperative learning, and guided discovery also were incorporated throughout the year. The three classes that received the more traditional instruction did not receive any direct problem-solving instruction or specific exposure to solving non-routine problems. At the end of the school year, students were interviewed and given problems to solve. In general, the students receiving direct strategy instruction and weekly challenge problems faired better at solving non-routine problems.

Bottge (1999) is concerned about teaching practices that withhold complex content from below average students until easier material is mastered. Bottge recommends engaging students in “challenging and meaningful problems” using contextualized or anchored instruction (p. 82). Anchored instruction is instruction that places students in a scenario students might encounter and allows them to explore the mathematics that occurs in that situation. It also allows the students to create some of the mathematical questions they would like to investigate in that context. In Bottge’s study, some remedial eighth-grade students received contextualized instruction and others did not. The contextualized, or anchored, instruction began with a series of video vignettes. These 15-minute segments provided stimulating and meaningful contexts and served as a springboard for more exploration. Just as in life, the problems were not explicitly stated, so the students determined what they were trying to solve. The descriptions of the discussion and interaction that took place as the students investigated these scenarios made it apparent that students were invested in the project. The final problem was to design and build two skateboard ramps within certain constraints. Bottage concluded that many of the students who were given complex, contextualized problems showed improvement in their problem solving.

Xin (2007) gave variously constructed multiplication and division word problems to U.S. and Chinese middle school students with learning disabilities. Many of the U.S. students relied on picture representations to help solve the problems, but none of the Chinese students did. All of the Chinese students attempted all of the 16 word problems on their assessment, whereas the U.S. students did not. In general, the Chinese students outperformed the U.S. students. Xin attributed this performance difference to a lack of numerous and varied problem-solving experiences by the U.S. students. He analyzed both U.S. and Chinese middle school math textbooks and found that U.S. texts frequently do not vary the surface structure of word problems or the position of the unknown in the problems, while Chinese texts do. Xin also noted that students struggled when a problem included a word, such as “times”, but solving the problem did not require multiplication. The U.S. students tested appeared to have an expectation for familiar problems to be worded in a specific way. He concluded that successful problem solvers have had practice accurately converting words to symbols.

The three studies demonstrate different viewpoints about what problem solving is. Higgins (1997) viewed problem solving as students solving a variety of grade-appropriate problems that do not have readily apparent solutions. The students might use strategies they were explicitly taught or they might come up with their own strategies. Bottge (1999) considered problem solving to occur when students were deeply involved in a stimulating context and created and answered the mathematical questions that they were interested in. In Xin’s (2007) study, problem solving was stated as the ability to correctly come up with the correct answer to word problems. All three studies proposed that students needed to be given repeated opportunities to do problem solving in order to improve. My action research had my students solving problems similar to those used in the Higgins research.

Strategies for Cooperative Learning

Currently, it is not out of the ordinary for students to work in groups when solving problems. Working cooperatively allows students to learn from one another, not just the teacher. Having students in groups creates its own sets of challenges, though. The teacher's desire for all students to be actively participating in each problem may be difficult to obtain, especially if some of the group members possess any weaknesses or learning disabilities. The following studies describe methods to help all students be involved.

Students may benefit from being explicitly taught a clear set of expectations before working in groups. Reciprocal teaching began as a strategy for improving reading comprehension. It is a structured strategy that "involves students making predictions when reading, questioning themselves about the ideas in the text, seeking clarification when confused, and summarizing content" (Pressley, 2002 as cited in van Garderen, 2004, p. 226). Van Garderen (2004) strongly suggests providing explicit instruction when introducing an adapted version of reciprocal teaching to math students. In this way, each student will know how the group is to function and what his or her role is. In this strategy, students are divided into small groups. After each member has silently read the problem, students ask one another if there are any vocabulary that need to be clarified. The group members help one another to identify the key parts of the problem and then devise a plan of how to solve it. Solving may be done individually or cooperatively. The majority of the discussion is transferred away from the teacher to among the students. This type of cooperative learning was found to be especially helpful when groups included students who were below grade level in reading. With reciprocal teaching, van Garderen suggests problem-solving comprehension can be improved.

In a study investigating the effects of expectation training prior to group work, Kroeger and Kouche (2006) had their 150 seventh-grade students work extensively in pairs. Students trained for five class periods to learn the roles and expectations of peer-assisted learning strategies, or PALS. While in pairs, students alternated taking on the roles of “coach” and “player.” Written scripts with the types of questions and statements the coach should make during cooperative learning were given to students. Students remained paired from five to nine weeks. This format was especially helpful in reinforcing difficult concepts. Kroeger and Kouche used a point sheet and saw all 150 students engaged during their entire math periods. They contributed this success to the coach/player structure and student interaction.

The articles by van Garderen (2004) and Kroeger and Kouche (2006) both suggested that students should be given clear guidelines about cooperative learning before students set out to work in groups. Van Garderen recommended students work in small groups while Kroeger and Kouche limited groups to pairs. Kroeger and Kouche documented 100% of their students on task. My study included students working in pairs, and sometimes I brought two pairs of students together to form small groups.

Student Beliefs

Teachers want their students to do their best. In order for this happen, teachers may want to challenge their students without overwhelming them. Student confidence levels, student beliefs about themselves, student beliefs about their abilities, and student attitudes toward mathematics have been the focus of many educational studies. However, one study may vary greatly from another.

Papanastasiou and Bottiger (2004) studied a math club at St. Paul's Episcopal Day School in Kansas City, Missouri. Approximately 100 fifth- to eighth-grade students attended a voluntary math club on Wednesday mornings for one hour before school. The problem format varied from week to week. Sometimes problems were printed in pairs, one easy and one harder. Sometimes the problems were part of a Bingo game and had to be completed mentally. Some problems were in the form of a paragraph with many blanks and an answer bank full of numbers to use. Students liked the non-threatening challenge and variety of these problems. The students who attended the math club were surveyed to determine the factors that accounted for the high rate of attendance (118 out of 163 students) at the club meetings. The survey contained questions to determine what the students liked about the club, why they attended the club, and their overall opinions about math. The researchers also wanted to examine how the math club contributed to the success of the whole school in the area of mathematics. Almost 90% of the students in the club considered themselves good in mathematics. All but one student responded that they also attend because they want to improve in math. Nearly half said they wanted to be among the best in school. Papanastasiou and Bottiger found positive attitudes to be associated with the math club. Scores on standardized tests were monitored. The researchers suggested the data showed "a very healthy and positive relationship between the student's mathematics attitude and achievement in relation to the mathematics club" (p. 169).

Students' self-beliefs influence students' level of interest and engagement (Falco, 2008). Falco created a curricular unit to investigate the math competence beliefs of 228 sixth-grade students. Of special concern were adolescent girls because their competence beliefs are strong indicators of academic performance and choices (Bandura, 1994, as cited in Falco, 2008). Over a nine-week period, the areas of time management, goal-setting, study habits, and help-seeking were addressed during math class. Students were taught strategies to use if they did not understand a concept. Attitude, self-confidence, enjoyment, and motivation regarding math all had improved by the end of the unit. Falco concluded the improvement was due to the nine-week unit, which fostered positive mathematical attitudes and self-beliefs. Falco also concluded that the curriculum met a specific need but that follow-up lessons might be necessary to maintain this result.

Papanastasiou and Bottiger (2004) and Falco (2008) had very different ideas about the best approach for fostering positive student beliefs. Papanastasiou and Bottiger used a club atmosphere of fun, competition, and doughnuts to improve student beliefs about mathematics and student ability. Falco took general study skills such as study habits and help-seeking and specifically modified them for mathematics. Falco determined that teaching students how to be mathematical advocates for themselves improved student beliefs. My study included creating a club atmosphere, but this math club was mandatory and occurred during the normal math class period.

Classroom Discourse

One possible goal in problem solving is arriving at the correct solution. However, increased learning and a better understanding of the problem may be considered an even greater goal. By allowing students to become fully involved in a problem and actively participate in its discussion, students may be better prepared to understand subsequent problems.

Webb, Nemer, and Ing (2006) provided students with direct instruction on how to work cooperatively. This instruction focused on students asking peers “specific rather than general questions, providing explanations rather than only answers on calculations, and encouraging active work rather that passive responses by help seekers" (p. 78). Group discussions were recorded and carefully coded. Results showed that when students gave help to their peers, they frequently followed the example of their teacher. Students asked questions that led to explanations, rather than yes or no answers, if that is what their teacher tended to do. Also, the students attempting to give the help would do most of the work, if their teacher usually did so. The authors recommend changing teachers' instructional strategies first and then focusing on specifically teaching students how to actively work in cooperative groups.

In order for the members of a class to achieve shared meaning during large-group problem-solving discussions, it can be beneficial if both agreement and disagreement occur. Nathan, Eilam, and Kim (2007) audio- and videotaped a group of 20 sixth graders working to decide how a pie could be cut into eight equal pieces with only three cuts. During this hour, 13 of the students took a very active role and presented their ideas, explanations, and sketches to their peers. Phrases, gestures, and facial expressions were analyzed, and frequently some members of the group would disagree with the explanations, while others would agree. The large group discussion oscillated back and forth between nearly reaching a consensus and back to disagreement. Nathan et al. assert that both facets should be encouraged during in-depth problem solving to allow students to assimilate what is being discussed with their prior knowledge.

Piccolo, Harbaugh, Carter, Capraro, and Capraro (2008) defined rich discourse as "interactive and sustained discourses of a dialogic nature between teachers and students aligned to the content of the lesson that addresses specific student learning issues" (p. 378). Piccolo, et al. coded 183 classroom videos from 48 sixth- through eighth-grade mathematics teachers from five school districts. Each video was chunked into 20-second segments so the types of interaction could be coded. Questions were categorized as teacher-generated or student-generated and further classified as probing or guiding. Teacher-to-student and student-to-student interactions were examined. Types of questions and explanations along with the sequence of questions were recorded. Open-ended questions that provoked more discussion were of particular importance. Patterns of discourse were found and were represented in graphical form. Exchanges that began with the teacher usually resulted in flat, one-sided conversations, rather than rich dialogue. They found that more student-generated questions led to a richer discourse. Piccolo et al. concluded that improving questioning techniques can help teachers improve instruction.

Webb et al. (2006), Nathan et al. (2007), and Piccolo et al. (2008) all found that the types of questions teachers ask play a very important part in classroom discourse. They also all found that student-to-student interactions tended to be richer than only teacher-student interaction. Webb et al. emphasized that students tended to mimic the behavior of their teacher when working in small groups. Nathan et al. used video data, including gestures, to conclude that some disagreement during a large-group discussion can be beneficial. Piccolo et al. called attention to the importance of student-generated questions in classroom discourse.

Conclusion

Types of problems, cooperative learning strategies, student beliefs, and classroom discourse are all facets of problem solving. By providing students with repeated opportunities to explore interesting and challenging problems with their peers, students will be better prepared for future problems (Nathan et al., 2007; Piccolo et al., 2008). In a safe, supportive environment, students can form questions and build upon their prior knowledge.

Bottage (1999) and Xin (2007) show that regardless of student achievement level, all students should have the opportunities to solve non-routine problems. By allowing students to work together, educators allow students to increase their chances for success. By carefully choosing the questions and by carefully monitoring discussions, teachers can encourage deeper conversations that have more meaning for their students.

My study was similar to the study done by Papanastasiou and Bottiger (2004), because I also investigated a math club. My study was different in that my club was mandatory and was held during regular math time. Their club was optional, and it met in the mornings before school. My study monitored discussions but was not videotaped and carefully coded like the study done by Piccolo et al. (2008).

Purpose Statement

The general purpose of this study was to determine if meeting weekly in a math club setting changed scores on problem-solving assessments given over the 12-week period and changed student attitudes toward problem solving. The impact of less teacher lecture and more student presentations also was examined in relationship to student attitudes about cooperative learning. The ultimate goal was to gain information about math clubs to help me better understand some of the best ways to incorporate problem solving in my middle school courses.

For the purpose of this study the following questions were investigated:

1. What will happen to students' problem solving accuracy after they have had frequent practice over an extended period of time and have received instruction modeling some problem-solving techniques?
2. What happens to students attitudes toward math and problem solving when they are a part of a mandatory math club?
3. What happens to my mathematics teaching when I have my students work in pairs or groups as they solve challenging and creative problems?

Method

Action research is designed to help educators pinpoint concerns they have in their classrooms and uncover solutions for them. Apart from the informal evaluations that many educators think through at the end of the day, action research focuses educators to plan their methods of data collection and analysis. The reflection completed at the end of the process allows educators to determine the value and impact of their research. Educators improve by applying the results to their own classrooms (Gall, Gall, & Borg, 2005). I conducted action research in my classroom in order to examine the changes in my teaching. This gave me the opportunity to spend time reading some current research about problem solving. It also gave me the opportunity to make changes and carefully note what happens in the classroom when those changes are made.

Data was collected from students in grade seven at a junior-senior high in a town of about 2,000 people in Southern Nebraska, during the 2008-2009 school year from January to April. All of the seventh grade students in my fifth period Transition Mathematics class were included. These students were 12 to 13 years old. The class of 15 students was composed of 10 females and five males. None of the students were in the special education program. A sophomore student assistant with a strong mathematical background was present each day to provide addition support to the students.

One purpose of my data collection was to monitor these students' problem-solving accuracy as they experienced weekly math club problem-solving practice over an extended period of time. The students also received instruction modeling some problem-solving techniques during this 12-week period. The problems for the weekly problem-solving activities came from the 2008-2009 MATHCOUNTS Handbook. A journal of teacher thoughts in selecting certain problems and designing problem-solving assignments was kept. Ten problems were given to the students each week for 12 weeks. During eight of the math club sessions, students were not allowed to use calculators. For four of the math club sessions, students were allowed to use calculators (see Appendix A).

Students' problem-solving assignments were collected and scored with a rubric (see Appendix B). Each problem was assigned a whole number ranging from 1 to 5. A maximum of 50 was possible for each math club session. Scores were not written as a fraction out of the maximum possible, but were simply written as a whole number from 1 to 50 because these were not being graded in the same manner as their daily assignments. Frequently, students were given some additional problems from the 2008-2009 MATHCOUNTS Handbook, but they were not scored using the rubric.

Similar problems were used to create a pre-test/post-test (see Appendix C). The instrument consisted of 10 items from the 1992-1993 MATHCOUNTS Handbook. These problems incorporated many concepts including number sense, geometry, algebra, and discrete mathematics. Students took the pre-test on January 28 and the post-test on April 22 and were not allowed to use a calculator on either test. The pre-tests/post-tests were scored with the same rubric as the weekly problem-solving activities (see Appendix B). I assumed that when taking the post-test they were not simply remembering their answers from the pre-test due to the long period between tests.

Between January 28 and April 22 students were interviewed in groups of 3 or 4 and asked questions in regard to problem solving (see Appendix D). The interviews were audio-taped. Later to analyze the data, notes were taken as the audiotapes of the interviews were replayed.

A second purpose of data collection was to study what happened to student attitudes toward math and problem solving when they were a part of a mandatory math club. One time I split the class into two teams, and the other time I had all of the students solve five problems independently. In both situations, I wanted to see which group (or individual) had the best solutions accompanied by good explanations. More importantly, I wanted to see how the element of competition would impact their attitudes. A journal to record observations of instances of outward signs of their attitudes about math and student behaviors was kept. Between January 28 and April 22, students were interviewed individually and asked about their attitudes toward math and their perceptions of its effects on their achievement (see Appendix E). The interviews were audio-taped. Students also were surveyed to assess their attitudes before and after the forming of the club (see Appendix F). Students responded to a Likert scale ranging from 1 to 5. Students took the attitudes survey on January 28 and again on April 22.

A third purpose of data collection was to examine changes in the mathematics teaching when students worked in pairs or groups as they solved challenging and creative problems. A log to record the minutes spent on group work was completed. A journal of observations of students working in groups and their interactions with one another was kept. After each weekly math club session, a journal entry was made noting my actions during the math club session. Between January 28 and April 22, students were interviewed in groups of 3 or 4 and asked about their thoughts on working in groups (see Appendix G). These interviews were audio-taped.

I also collected data by answering a set of 15 questions in a teacher journal (Appendices H, I, J). Every week I completed a journal about the problem solving, math attitudes, and cooperative learning that occurred during the Math Club session that week. Twelve journal entries were made beginning on January 28 and ending on April 15.

Findings

Over the course of this 12-week action research project, one day a week was devoted to math club, and the remaining days were focused on the content in the textbook. On Math Club days, the students were always given 10 problems. Because I wanted the students to have a sense of fun and adventure, I changed the format of math club from week to week to keep students guessing about what types of activities the class would be doing that day: sometimes students worked in pairs, sometimes they worked in small groups of 3 or 4, and sometimes in large groups of 7 or 8. On two of the Math Club Days, I stopped them every 15 minutes and awarded points to the groups with most correct answers, and on nine occasions they tried all of the problems and then focused on planning a presentation of one of their solutions. Once there was a little competition between one half of the room and the other half. On 10 occasions I had them take the problems home to finish, and twice I had them turn in what they had at the end of the class period. The students commented that they liked the change of pace and not knowing exactly what they were going to do each week.

My inquiry yielded that students did improve their problem-solving accuracy, although that varied according to the difficulty of the problems. In just a few weeks, they did become accustomed to solving a variety of problems. The students overwhelmingly liked working together, even some of the students who were introverts. My teaching was definitely different on the days when we had math club. The students really began to rely on one another instead of me, and I spent very little time at the front of the room.

My first research question was, “What will happen to students’ problem-solving accuracy after they have frequent practice over an extended period of time and receive instruction modeling some problem-solving techniques?" I asserted that my students, after being given multiple opportunities to solve a wide range of problems, would become better at stopping and carefully determining what the problem was asking for.

My students gradually began doing better and better on their 10 problem-solving problems each week. A sample of one student's work from February 4, 2009, and again on April 8, 2009, is shown at Appendices K and L. At first I think these problems were so different from what they had been doing that they appeared taken off guard. When we first started math club, the students usually briefly consulted one another and then jumped into doing some calculations without giving exactly what they were being asked for much thought. In my journal for the fourth math club, I noted the students had a set of problems with a question that was a little unusual in its wording, "A student came to me today and said, 'I don't understand this problem. I don't even know what it means.' She wasn't the only one" (Teacher Journal, February 18, 2009). On that day, they wanted to consult me regarding the wording because they knew that any misinterpreting of the question would lead to an incorrect solution. I noted in subsequent journal entries that students became very aware and concerned about the wording of the problems they were given. "When listening to the students today, I was surprised at the number of groups I heard having an intense discussion with each other about the intent of the problem" (Teacher Journal, March 11, 2009). My students really wanted to understand what was being asked so that they could do the problem correctly. They did not want to waste time finding something if that was not what they were being asked to find.

In the interviews, students overwhelmingly stated they preferred working in groups. A student adamantly said, "It's way better working in groups. We can talk about everything." (Student Interview, February 27, 2009) One of the main reasons a few students gave was that sometimes when they read the problem they did not understand the problem. By discussing the problem with someone else, the comments from their peer gave them a fresh viewpoint of what was being asked, and the interaction can make the problem much clearer. During one of the interviews, a student commented about how important it was to understand the problem before they began: “Yeah. When I’m by myself, a lot of times I get confused. When I have someone else to talk it over with, it really helps me understand what we are supposed to do” (Student Interview, February 6, 2009). The student also noted that was one of the reasons he enjoyed working in groups; he liked to be able to discuss the question with others to make sure he understands what it is asking.

As I paid attention to students trying to decode problem phrasing on Math Club days, I also discovered that some of my students had lower reading comprehension skills than I had realized. I wrote in my journal, “I know that Mrs. Corman has some kids in a separate reading group. I assumed all of these kids were OK because they do fairly well with the problems in the textbook. I need to talk to her because it seems one or two of these kids are struggling” (Teacher Journal, April 1, 2009). These students frequently relied on their partner to understand problems during Math Club. Reading is my school’s improvement goal, and I think all of my school’s students would benefit from more opportunities to read and make sense of interesting problems.

On the weekly set of 10 problems, I observed my students’ working habits and noticed many of the students were becoming more confident problem-solvers: “The kids are doing such a better job when I hand out the problems. They don’t seem scared or at a loss of what to do, like they were the first couple of times” (Teacher Journal, February 11, 2009). After a few weeks, most of the students were no longer deterred by complicated wording. They went ahead and tried the types of problems they were previously skipping. After participating in math club for 12 weeks, the students rarely gave up when they were given a difficult problem but worked diligently and gave it their best attempt. After our ninth Math Club I wrote, “When we started all of this, the kids would just skip over quite a few of the problems. Now they still skip a few of the really hard ones, but it’s as if they really believe they can solve most of these” (Teacher Journal, March 25, 2009). As a whole, my pupils have become much better about reading and re-reading the problem to make sure that they have a good understanding of what the problem is asking for. Looking back at many of the problems they have solved, when a problem was worded very clearly, more of the students answered it correctly. Often it was not the actual mathematical difficulty of the problem but the wording that appeared to impact the number of students who answered the question correctly.

I also asserted that students would take more ownership of the problems they are solving when they present some of their solutions to their peers. I saw a jump in the points my students earned on their weekly problem-solving activities once they started doing presentations. No presentations were made during the first three weeks. Once groups started taking turns presenting problems on the board, they began to really dig into the problems. They had the opportunity to see that at times some of the other groups did not know where to begin, and they found out the processes and the strategies that other groups used. The day students began presenting I wrote in my teacher journal, “The change in the dedication to the problems today was remarkable. It seemed to change their whole outlook when they knew that they would be presenting a solution to the rest of the class” (Teacher Journal, February 18, 2009).

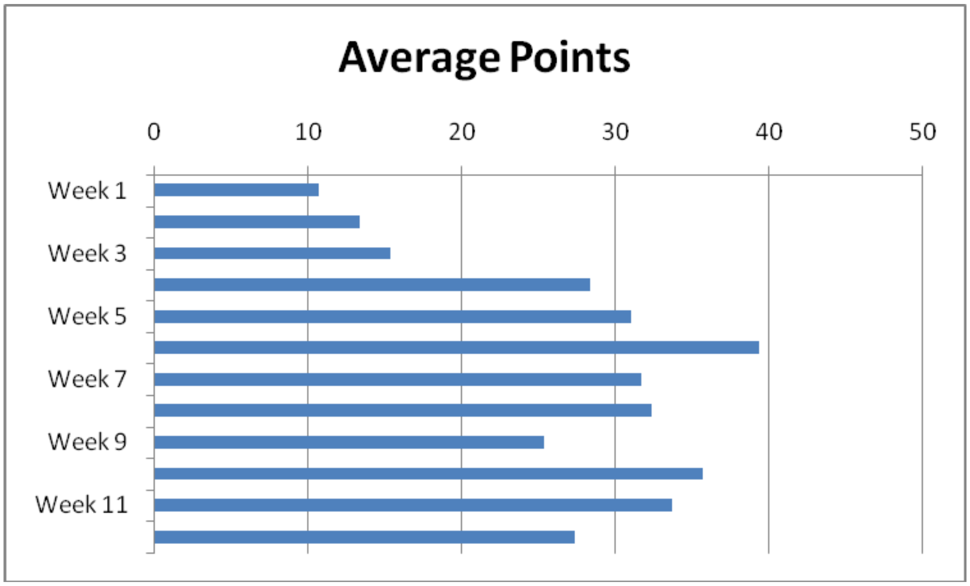

Figure 1. Average Points scored on weekly Math Club assignments

It was very clear in the interviews that the students were gaining a lot from the presentations made by their peers. Some of the groups presented solutions that were incorrect, and the class was able to discuss the problem and eventually reach a consensus on the solution. In the interviews, the students liked that their peers were non-judgmental. During an interview a student said, "Our group made a mistake when we put our problem on the board. It was alright because we talked about it and fixed it" (Student Interview, April 3, 2009). In my journal, I noted the willingness of the students to attack the problems, especially if they knew it was a problem they might be presenting,

Today when I announced that each group would present a solution, many of their eyes got wide, and they began to rapidly search for one of the 10 problems on the sheet that everyone in the group agreed would be good to present. (Teacher Journal, February 18, 2009)

My second research question was, "What happens to students' attitudes toward math and problem solving when they are a part of a mandatory math club?" I asserted that student interest can be piqued and attitudes toward math can be improved when a small amount of competition is inserted into student learning. On the two occasions when I added an element of competition, both of my journal entries noted that most of the students did get very excited. I wrote in my journal, “We split into teams today, and the kids became very pumped up, especially the ones in my group” (Teacher Journal, March 18, 2009). In an earlier journal I wrote, “When I had them compete as individuals, most were extremely focused and happy” (Teacher Journal, March 4, 2009).

My students commented during the interviews that they did like the element of competition that I gave them a couple of times. One student commented, “I really liked when we had the competition. I really wanted our group to win” (Student Interview, March 20, 2009). Another commented, “The class period flew by that day” (Student Interview, March 20, 2009). They also commented that they looked forward to an upcoming area math competition. During an interview, a girl commented, “I hope I get to go to the competition in May” (Student Interview, April 17, 2009). My students’ work from the individual competition was some of the most accurate problem solving that my students did on Math Club problems. Most of the students were very proud to turn their work in. In my teacher journal I wrote, “As the students brought me their solutions, most of them had big smiles on their faces. I sensed that they were pleased with themselves” (Teacher Journal, March 4, 2009).

When we did the competition between the two groups, one of the groups had excellent solutions, but the other group’s solutions were lacking. As that group of eight students discussed the problems, one student entered what they discussed in a calculator. Unfortunately, only solutions were written down. When it was time present to the class, there was no agreement on what had been entered into the calculator, which caused frustration. I believe that this was due, in part, to the fact that I was the reference person for the higher achieving group, and the sophomore student assistant was the reference person for the other group.

When the prompt “I like competing for answers” appeared on the January student attitudes survey (see Appendix D for survey and Figure 2 for results), three students chose *disagree*, five students were *neutral*, four chose *agree*, and three chose *strongly agree*. When the survey was given again in April, two students had a neutral response, seven students selected agree, and six students selected strongly agree. When asked during one of my last interviews, a student said, “I think competition can be good. It is a challenge, and I look forward to that” (Student Interview, April 17, 2009). I believe that the students like competition because they have something to contribute to the group as a whole and they each have areas they are strong in.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I like being with my friends during mathematics club.	**0**	**0**	**0**	**6**	**9**
I like the relaxed way of learning that is used during mathematics club.	**0**	**0**	**0**	**5**	**10**
I feel confident when I see word problems.	**4**	**5**	**3**	**2**	**1**
I like working in groups during mathematics club.	**0**	**0**	**1**	**7**	**7**
I like math, in general.	**1**	**3**	**3**	**5**	**3**
I like group activities.	**0**	**1**	**2**	**7**	**5**
I like using calculators during mathematics club.	**0**	**1**	**4**	**5**	**5**
I like working together to learn mathematics skills during mathematics club.	**0**	**1**	**3**	**7**	**5**
I like that the problems are harder than in regular mathematics class.	**2**	**3**	**2**	**4**	**4**
I like competing for answers.	**0**	**0**	**2**	**7**	**6**

I learn more mathematics because of mathematics club.	**1**	**2**	**5**	**4**	**3**
The math club is more fun than regular class.	**0**	**0**	**0**	**6**	**9**

Figure 2. April Math Club Survey Results

My third research question was, "What happens to my mathematics teaching when I have my students work in pairs or groups as they solve challenging and creative problems?" I asserted that my teaching was less teacher-centered and more student-centered when students worked together to solve problems. In my journal, I noted many times how much I enjoyed interacting with the students in the capacity of a facilitator when they were solving problems. My second teacher journal entry stated, "It certainly was refreshing to be able to stand back a little and just see what the kids can do. They talk up a storm with their partner, and it is enlightening to hear the conversations" (Teacher Journal, February 4, 2009). After our fifth session of math club I wrote, "I barely talked at all today. I feel that I am getting to know the students and their abilities better by listening to what they have to say" (Teacher Journal, February 25, 2009). I was not up at the board teaching: either the students were collaborating with one another or they were presenting to their peers. I kept track of the minutes I spent at the board or talking to the group as a whole when we were problem solving. Each week it was five minutes or less, except once when I gave a little help to a group struggling with its presentation.

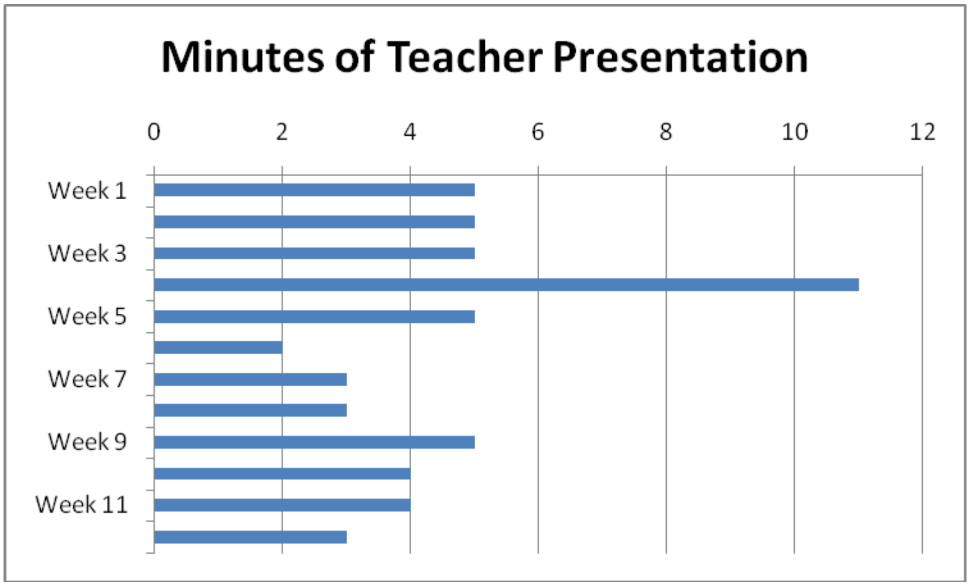

Figure 3. Weekly minutes of teacher presentation on Math Club day.

Every week I wrote in my journal about a student who amazed me and jumped out as being extremely “on the ball.” The entry was almost never about a student I would have expected, and it changed from week to week. The student usually used some strategy that I had not thought of. This provided me an opportunity to learn more about the individuals in my classroom and their talents and skills.

Additionally, by talking to the kids more casually, I got more insight into how they went about solving the problems. I found that often I would not really understand the students’ ideas without slowing down and having conversations with them. During some of my last interviews I received the most boisterous responses when I asked about the times when I was not teaching at the board. I asked students if they felt comfortable working with everyone. One girl said, “Yes. Everyone is nice. We catch each other’s mistakes and accomplish more. When you teach, I usually don’t catch my mistakes” (Student Interview, April 3, 2009). The students prefer to be at the center of the discussion, rather than me talking at them. One student said, “I enjoy talking with each other rather than just sitting in my seat and listening and raising my hand” (Student

Interview, March 27, 2009). Another commented, “I really enjoy the times when I can explain my ideas to my partner, then I get to hear what they think” (Student Interview, March 27, 2009). They especially liked getting the chance to explain their ideas and methods to others when they did the problem in a way different from everyone else. One student said, “I liked when I came up with making a table and put it on the board. No one else though of that” (Student Interview, February 27, 2009). Many times I found that some of their methods were much “sleeker” than the one method I would have shown them if I had taught a method to the entire class as I usually do. These interviews were so insightful to my teaching, and the students were appreciative that I was interested in what they had to say.

Students consistently commented in the interviews that they liked working with one another. I think this was in contrast to many days when we used context from the textbook, and I did a large portion of the talking. Students commented that they really enjoyed the times when they took on the role of the leader or the teacher and got to explain their ideas to their friends. A student commented during an interview, “On the problems I understand, I liked being able to help out someone who is not getting it” (Student Interview, March 27, 2009). I believe that each of the students had the opportunity to do this during the 12-week period. I think that when students worked together I actually had the opportunity to understand them and their thought processes better because I got to hear them discuss their thought processes with their peers. This allowed me to gain new insight into where their difficulties were and where they were doing quite well. My seventh teacher journal states, “I assumed that these kids had an average understanding of prime numbers. Today when they were working together, I heard many incorrect discussions about what it means to be prime” (Teacher Journal, March 11, 2009).

Conclusions

As a teacher, this study reminds me what an important part expectations play in the classroom. Prior to this study, at times I had chosen to omit certain problems because they might be too difficult or because I was afraid that some of my students would struggle with them. Unfortunately, those expectations limited the learning opportunities for my students. This study demonstrated to me that even though the students were unfamiliar with this type of problem solving, in a few weeks, they were all at or above my expectations.

My findings supported some of the research articles that I read that looked at student discussions. In-depth discussions between students are necessary and important. The need of every student be heard is very important. Creating an environment that encourages the “rich discourse” that Piccolo et al. (2008) wrote about is indispensable. The more abstract the concepts, the more the students need the opportunity to talk through their ideas.

There were similarities in our findings. They found that their math club had a positive impact on student attitudes, and so did I. They also noted a gain in student mathematical ability. I saw gains with my students in their ability to problem solve. They surveys found that the students liked these activities. My surveys also showed that students were pleased to have class periods that were not teacher lecture.

Implications

In my school, where many of the students take Algebra I as eighth graders, I am even more convinced that seventh grade is an important time to focus on problem solving. The Algebra I course is very full of brand new content and many applications. This leaves less time for creative non-routine problem solving to be focused on. The goal of these applications usually is to get the students to apply the skill they learned in that lesson to a particular situation. The seventh grade course spends some chapters reviewing and, with careful planning, lends itself to spending more time problem solving. Because students transition from the elementary to the high school is between sixth and seventh grades in my district, I believe that this is one more reason to set the expectation on frequently problem solving when seventh grade begins. I think the students will easily adjust to that expectation.

This study also has convinced me to give future students the chance to work together. Small group work was a topic that generated many favorable student comments. It offered more opportunities for students to be the expert. I also plan to do student interviews during class time that are not audio-taped next year. It also would be a good way to ask how they went about solving their math problems. Because I believe the students liked the competitions because they were very much out of their normal routine, I will continue to incorporate some elements of competition on a random basis with my middle school students. I will work very hard to make sure not to create cut-throat situations, but create an atmosphere that is very positive.

I will share my results with the other middle school math teacher in my building. I will also share the favorite problems of my students. If I decide to do a new study, I would like to compare the problem-solving scores of students that have used a calculator on their daily assignments and assessments with students that have not used a calculator on assignments or assessments. I think that the scores would be similar.

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Appendix A

Workout 3

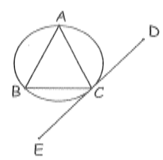
. ________ mph A car is scheduled to make a 616-mile trip in 9 hours. The ccr averages 60 mph during the first 240 miles and 80 mph during the next 160 rriles. What must the average speed of the car be for the remainder of the trip ir order for the car to arrive on schedule?

. ________ revs  The front and rear wheels of a horse-drawn buggy had radii of 14 in. and 30 in., respectively. In traveling one mile (which is 63,360 inches), what was the positive difference in the number of revolutions made by the front and rear wheels? Express your answer to the nearest whole number.

. ________ feet Rex runs one mile in 5 minutes, Stan runs one mile in 6 minutes and Tim runs one mile in 7 minutes. There are 5280 feet in one mile. By how many feet does Tim trail Stan at the moment that Rex completes a one-mile run? Express your answer as a decimal to the nearest tenth.

. ________ cu yds A rectangular solid box measures 2.75 feet by 4.05 feet by 480 inches. In cubic yards, what is the volume of the box? Express your answer as a decimal to the nearest tenth.

. ________ degrees In the diagram to the right, triangle ABC is inscribed in the circle and $AC = AB$. The measure of angle BAC is 42 degrees and segment ED is tangent to the circle at point C. What is the measure of angle ACD?



. ________ A set of data includes all of the positive odd integers less than 100, the positive, two-digit multiples of 10, and the numbers 4, 16 and 64. All included integers appear exactly once in the data. What is the positive difference between the median and the mean of the set of data? Express your answer as a decimal to the nearest thousandth.

. $ ________  Ryosuke is picking up his friend from work. The odometer on his car reads 74,568 when he picks his friend up, and it reads 74,592 when he drops his friend off at his house. Ryosuke's car gets 28 miles per gallon, and the price of one gallon of gas is $4.05. What was the cost of the gas that was used for Ryosuke to drive his friend home from work?

________ What is the greatest common factor of 84, 112 and 210?

________ days If 10 men take 6 days to lay 1000 bricks, then how many days will it take 20 men working at the same rate to lay 5000 bricks?

). ________ Ayushi has six coins with a total value of 30 cents. The coins are not all the same. Two of Ayushi's coins will be chosen at random. What is the probability that the total value of the two coins will be less than 15 cents? Express your answer as a common fraction.

Appendix B

MATH CLUB Name ___________ DATE ____________

CATEGORY	**Exemplary 5**	**Good 4**	**Average 3**	**Below Average 2**	**Good Try 1**
Question 1	You have a complete and correct solution with work organized and neat with good explanations.	You have a complete and correct solution. Your work is hard to follow or your work is sloppy.	You have a correct solution but you are missing key components of work needed to make your conclusion.	You have an incorrect solution with a minor error in your work.	You have an incorrect solution with a major error in your work.
Question 2	You have a complete and correct solution with work organized and neat with good explanations.	You have a complete and correct solution. Your work is hard to follow or your work is sloppy.	You have a correct solution but you are missing key components of work needed to make your conclusion.	You have an incorrect solution with a minor error in your work.	You have an incorrect solution with a major error in your work.
Question 3	You have a complete and correct solution with work organized and neat with good explanations.	You have a complete and correct solution. Your work is hard to follow or your work is sloppy.	You have a correct solution but you are missing key components of work needed to make your conclusion.	You have an incorrect solution with a minor error in your work.	You have an incorrect solution with a major error in your work.
Question 4	You have a complete and correct solution with work organized and neat with good explanations.	You have a complete and correct solution. Your work is hard to follow or your work is sloppy.	You have a correct solution but you are missing key components of work needed to make your conclusion.	You have an incorrect solution with a minor error in your work.	You have an incorrect solution with a major error in your work.
Question 5	You have a complete and correct solution with work organized and neat with good explanations.	You have a complete and correct solution. Your work is hard to follow or	You have a correct solution but you are missing key components of work	You have an incorrect solution with a minor error in your work.	You have an incorrect solution with a major error in your work.

		your work is sloppy.	needed to make your conclusion.		
Question 6	You have a complete and correct solution with work organized and neat with good explanations.	You have a complete and correct solution. Your work is hard to follow or your work is sloppy.	You have a correct solution but you are missing key components of work needed to make your conclusion.	You have an incorrect solution with a minor error in your work.	You have an incorrect solution with a major error in your work.
Question 7	You have a complete and correct solution with work organized and neat with good explanations.	You have a complete and correct solution. Your work is hard to follow or your work is sloppy.	You have a correct solution but you are missing key components of work needed to make your conclusion.	You have an incorrect solution with a minor error in your work.	You have an incorrect solution with a major error in your work.
Question 8	You have a complete and correct solution with work organized and neat with good explanations.	You have a complete and correct solution. Your work is hard to follow or your work is sloppy.	You have a correct solution but you are missing key components of work needed to make your conclusion.	You have an incorrect solution with a minor error in your work.	You have an incorrect solution with a major error in your work.
Question 9	You have a complete and correct solution with work organized and neat with good explanations.	You have a complete and correct solution. Your work is hard to follow or your work is sloppy.	You have a correct solution but you are missing key components of work needed to make your conclusion.	You have an incorrect solution with a minor error in your work.	You have an incorrect solution with a major error in your work.
Question 10	You have a complete and correct solution with work organized and neat with good explanations.	You have a complete and correct solution. Your work is hard to follow or your work is sloppy.	You have a correct solution but you are missing key components of work needed to make your conclusion.	You have an incorrect solution with a minor error in your work.	You have an incorrect solution with a major error in your work.

Appendix C

Math Club Beginning and Ending Assessment

1. What is the result when the greatest common factor of 6,432 and 132 is increased by 11?

2. Evaluate: $5 \cdot 11^2 - 3(\cdot 1 - 4 / 2 \cdot 3)$

3. In how many distinct ways can 3 green and 2 blue chips be arranged in a row?

4. The diameter of the base of a right circular cone is 16 inches and the height is 9 inches. What is the volume of the cone in cubic inches? Express your answers in terms of Π.

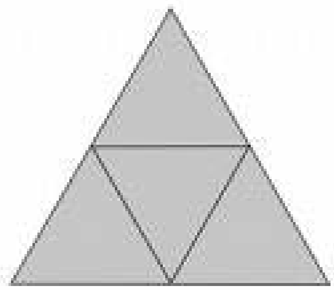
5. Rounding to 2 significant digits, use scientific notation to evaluate:
   $$\frac{(8.1 \times \cdot 10^3)(4.5 \times 10^3)}{9.0 \times 10^4}$$

6. Solve for x: $5 - [x + (3 - 2x)] = 2[x - 3(2 - x)]$.

7. A cylinder has a radius of 3 centimeters and a height of 2 centimeters, while a second cylinder has a radius of 2 centimeters and a height of 3 centimeters. What is the ratio of the volume of the first to the volume of the second?

8. Arthur wants to be certain his average is at least 90 for the first grading period. His first five test scores were 76, 95, 88, 99, and 83. The teacher plans one more test. What is the lowest score Arthur can get on this test and achieve the desired average?

9. A sweater is marked down 40%. The store announces a special one-day sale which reduces the sale price by 60%. What percent markdown on the original price does this represent?



Appendix C

1. ______

2. ______

3. ______

4. ______

5. ______

6. ______

7. ______

8.______

9.______

10. The percent shaded is ______

Mathcounts 1992

Appendix D

Student Interview Questions
Small Group Interview
Regarding Problem Solving

1. How helpful are the problem solving strategies that we have discussed?

2. Which problem solving strategy have you used the most?

3. Do you feel that you are making improvements in problem solving?

5. What are your thoughts on explaining your problem solving?

6. Do you feel confident when approaching problems?

7. What types of obstacles have you had when solving problems?

Appendix E

Student Interview Questions
Individual Interview
Regarding Math Attitudes

1. What are some of your current likes about mathematics?

2. What are some of your current dislikes about mathematics?

3. Do you enjoy math club?

4. What are your favorite parts about it?

5. If there was something you could change about math club, what would it be?

6. Do you like the feeling of competing?

7. Do you like to feel challenged?

Appendix F

Math Club Survey

Strongly disagree 1; Disagree 2; Neutral 3; Agree 4; Strongly agree 5

I like being with my friends during mathematics club.
1 2 3 4 5

I like the relaxed way of learning that is used during mathematics club.
1 2 3 4 5

I feel confident when I see word problems.
1 2 3 4 5

I like working in groups during mathematics club.
1 2 3 4 5

I like math, in general.
1 2 3 4 5

I like group activities.
1 2 3 4 5

I like using calculators during mathematics club.
1 2 3 4 5

I like working together to learn mathematics skills during mathematics club.
1 2 3 4 5

I like that the problems are harder than in regular mathematics class.
1 2 3 4 5

I like competing for answers.
1 2 3 4 5

I learn more mathematics because of mathematics club.
1 2 3 4 5

The math club is more fun than regular class.
1 2 3 4 5

Appendix G

Student Interview Questions
Small Group Interview
Regarding Group Work

1. Do you prefer working in groups?

2. Do work together on problems or do you work as individuals sitting next to each other?

3. When working in groups, are you able to focus on math or are you distracted by others?

4. Do encourage each other and ask each other questions?

5. Do you compete with each other in a positive way?

6. Do you think you learn more working in groups? Why or why not?

7. How do you handle different strategies or answers in the group?

Appendix H

Teacher Journal Prompts
Regarding Problem Solving

1. Did you do any direct instruction regarding problem solving strategies today?

2. Are students making improvements in problem solving?

3. Are students progressing in explaining their problem solving?

4. Do students appear to be confident when approaching problems?

5. What types of obstacles are students having with their problem solving?

Appendix I

Teacher Journal Prompts
Regarding Math Attitudes

1. What outward signs did you observe today regarding student attitudes toward mathematics?

2. What things did I hear students say regarding their thoughts or feelings about mathematics?

3. Did students appear to be happy about working on these types of mathematics problems?

4. Are their any specific students that could use some extra encouragement?

5. Were you surprised by any of the attitudes toward math that you observed today?

Appendix J

Teacher Journal Prompts
Regarding Group Work

1. How many minutes did students spend working in groups?

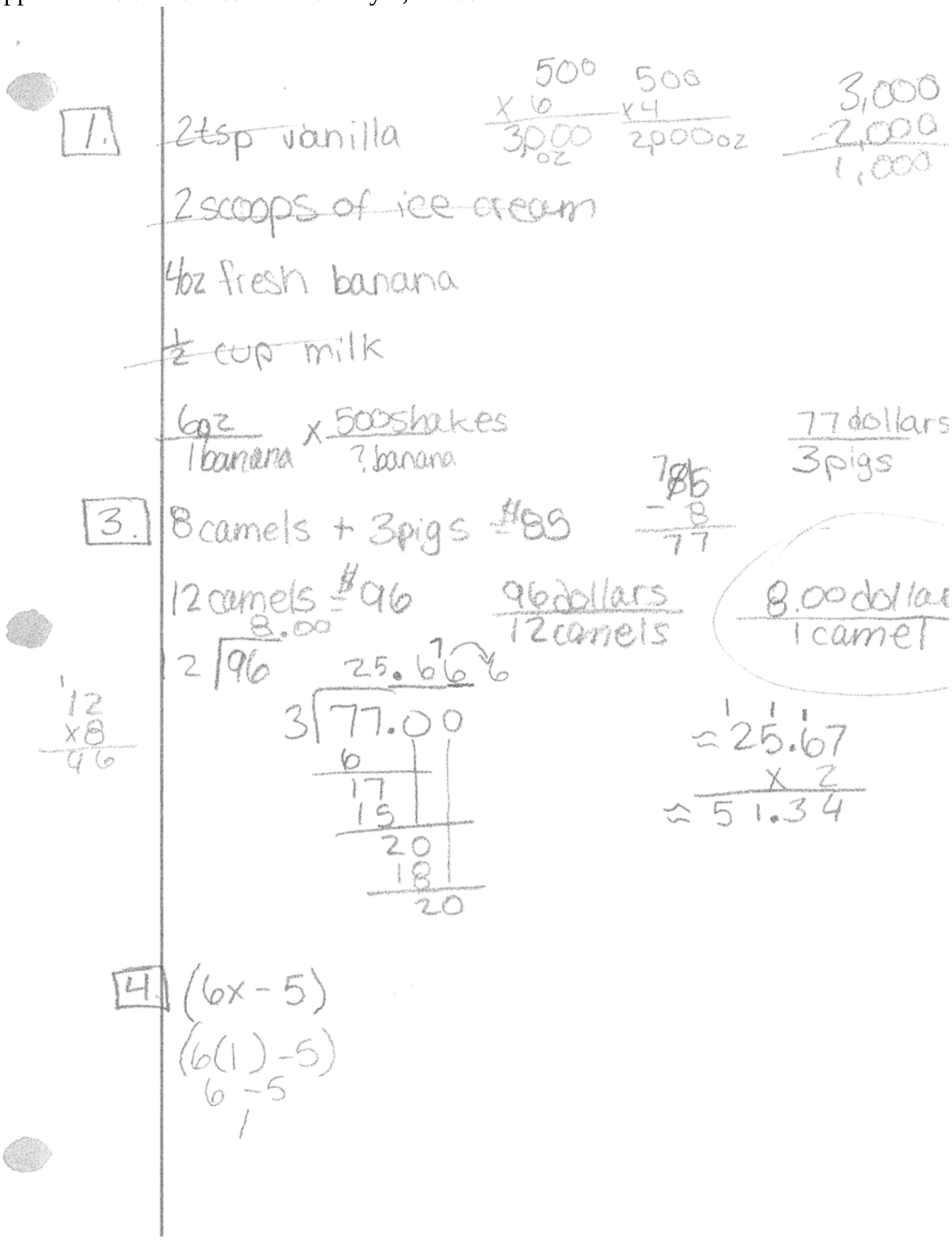
2. Did students truly work together or did they work as individuals sitting next to each other?

3. Did students use their time well or were they distracted by each other?

4. Did students encourage each other and ask each other questions?

5. Did students compete with each other in a positive way?

Appendix K. Student Work February 4, 2009.


1. ~~2tsp vanilla~~ 500 × 6 = 3,000 oz; 500 × 4 = 2,000 oz; 3,000 − 2,000 = 1,000

~~2 scoops of ice cream~~

4oz fresh banana

~~1/2 cup milk~~

6oz / 1 banana × 500 shakes / ? banana

3. 8 camels + 3 pigs = #85; 85 − 8 = 77; 77 dollars / 3 pigs

12 camels = #96; 96 dollars / 12 camels; 8.00 dollar / 1 camel

12) 96 = 8.00; 12 × 8 = 96

3) 77.00 = 25.666; ≈ 25.67 × 2 ≈ 51.34

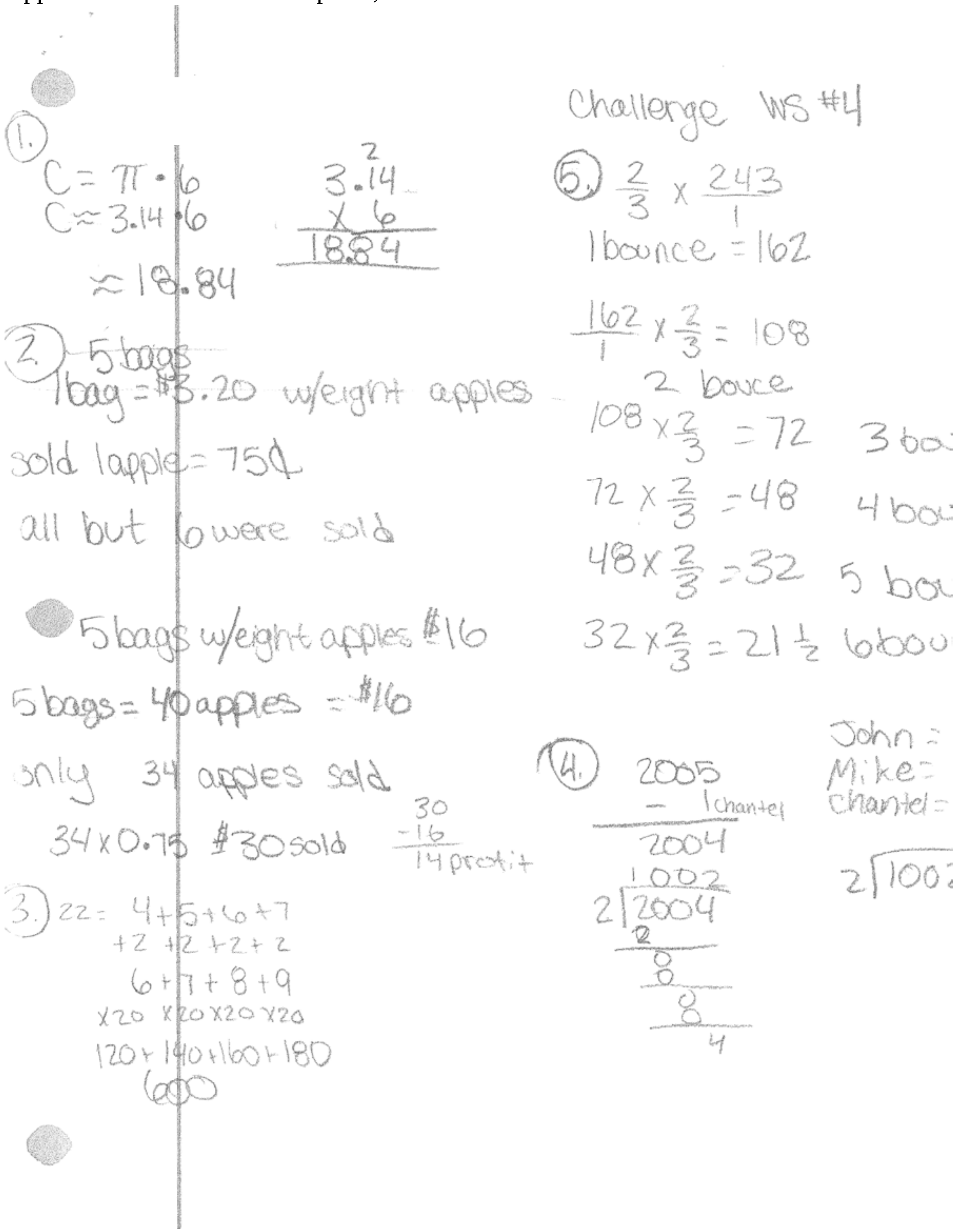
4. (6x − 5)

(6(1) − 5)

6 − 5

1

Appendix L. Student Work April 8, 2009.


Challenge WS #4

1.) C = π • 6
C ≈ 3.14 • 6
≈ 18.84

3.14 × 6 = 18.84

2.) 5 bags
1 bag = $3.20 w/eight apples
sold 1 apple = 75¢
all but 6 were sold

5 bags w/eight apples $16
5 bags = 40 apples = $16
only 34 apples sold
34 × 0.75 $30 sold
30 − 16 = 14 profit

3.) 22 = 4 + 5 + 6 + 7
+2 +2 +2 +2
6 + 7 + 8 + 9
×20 ×20 ×20 ×20
120 + 140 + 160 + 180
600

5.) 2/3 × 243/1
1 bounce = 162
162/1 × 2/3 = 108 2 bouce
108 × 2/3 = 72 3 bo
72 × 2/3 = 48 4 bou
48 × 2/3 = 32 5 bou
32 × 2/3 = 21 1/2 6 bou

4.) 2005
− 1 chantel
2004
2 | 2004 = 1002

John =
Mike =
Chantel =
2 | 1002