8-2014

An Authentic Mathematics Problem Competition and Its Effect on the Performance of Advanced Sixth Grade Learners

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An Action Research Report

By Eric Bergerson

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Submitted on August 10, 2014

in fulfillment of final requirements for the MAED degree

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Abstract

The purpose of this study was to determine what effect an authentic mathematics problem competition would have on student performance by advanced sixth grade learners. The study was conducted in a public elementary school, in a sixth grade math classroom with twenty five advanced math students. The data sources included a student survey, weekly competition problems, chapter tests, and field notes. The results showed a definite relationship between success in the competition and improved performance in the math class. For students who did well in the competition their chapter test scores improved during the five weeks of the competition. Also, teacher observations saw advanced student engagement and enthusiasm towards math increase. As a result, an authentic mathematics problem competition does affect the performance of advanced sixth grade learners.

Many important decisions go into being a successful mathematics teacher. Some of these decisions include structuring the time, assessing students, breaking down content to make it understandable, and meeting the needs of all learners. One of the most important decisions is what approach a teacher will take to teaching mathematics. In the United States, there are at least two main approaches to teaching mathematics. They include the traditional approach and problem based instruction. Ellet (2011) described the traditional approach as being teacher centered. The traditional approach consists of the teacher holding and presenting the content while the students process it. This approach is the most common one because it has been around the longest. Most teachers use it because that is the way they were taught mathematics. Ellet defined problem based instruction as student centered. This is where the students come up with their own strategies and solving techniques and the teacher is there to guide as needed.

My 6th grade math classroom consists of 26 above average math students. Because they are all above grade level, I am teaching them from the 7th grade math curriculum. The struggle I have is keeping the advanced students engaged while still meeting the needs of students who struggle with the 7th grade math concepts. In the past I have catered to the struggling students and have watched the advanced students become more disengaged as the year goes on. I believe my traditional style of teaching has bored the advanced students while confusing the struggling students. My hope is that switching my approach to problem based instruction will help all students. Hopefully the advanced students will become more engaged and the struggling students will not get confused by rules and procedures.

As the United States has fallen behind in the world's mathematics rankings, some teachers have concluded that the traditional approach is not the most efficient method of teaching mathematics (Gasser, 2011). Gasser writes that problem-based instruction, student-led solutions, risk taking, fun, and collaboration time are 5 components that will help students gain the skills necessary to succeed in today's ever changing global economy.

Many teachers think they are doing these components, but Gasser (2011) goes on to describe what each of these actually looks like. For example, problem-based instruction needs to be based on real-life problems that are not simplistic in nature. Gasser explains that in many Asian countries that performed highly on the Program for International Student Assessment (PISA), the main focus is to present students with problems that are meaningful to their current and future lives. They need to be high interest and high complexity in order to be good problems.

One example of a problem that Gasser (2011) gives can be used in a high school lesson. While learning about linear equations, a teacher can pose a question about cars and gas mileage that includes which cars would save the most money. These types of problems make students have to sift through a lot of information about gas mileage and prices. It also is high interest because many high school students are interested in driving and money. So the success of problem-solving lies in the selection of the problems.

Gasser (2011) also goes on to give details about the other four components. He states that student-led solutions are an important component in math because students need to be given the chance to solve problems before being shown what to do. If students are always shown, they do not get to use analyzing skills and often times, the teacher is then doing most of the work. Gasser explains that students should be given a chance to solve challenging problems and then compare with each other. Even if a student gets it wrong, they will be more engaged in finding a solution if they can compare their approach with other peers or the teacher's approach.

Gasser (2011) then describes how the risk taking component has to do with how we view failure in class. He writes that failure needs to be viewed as a part of life from which we learn. In Taiwan, students are routinely sent to the chalkboard to solve problems in front of the class. They are encouraged to work without fear. In China, students understand that they will face failures. However, they also know that they will get another chance to succeed. Also, Gasser describes how a teacher in the US can start out the year by having students go up to the board to solve problems. If a teacher focuses on the positives and manages the class in a way that promotes a safe place to be wrong, it will create an environment where students see mistakes as learning experiences.

Many of today's students do not see the meaning of memorizing facts, steps, formulas, and rules. They want to know why the formulas and rules work and why they are important. This is a major reason why problem based instruction is successful. It gives students engaging, real life problems that create a desire to investigate mathematical truths (Erickson, 1999).

As a mathematics educator, I struggle to help students reach their full potential. A common problem in my math class has been getting the struggling students to understand the concepts while challenging the advanced students. Unfortunately, I have also seen a lack of motivation from the advanced students. Because the traditional approach does not challenge the advanced students in my math class, I decided to conduct an action research project to see if an authentic math problem competition would affect student performance by advanced 6th grade learners. The action research was conducted in a 6th grade elementary math classroom. The research took place in a leveled math class consisting of the top 25 math students in the grade level. All of the students in my 6th grade classroom were given 7th grade curriculum to better meet their needs as learners. There were ten girls and fifteen boys. Two of the students were English Language Learners (ELL). All of the students scored above 6th grade level in math on all standardized tests. However, some students were barely above, while others were significantly above.

Before conducting the action research in my math class, I investigated using problem based instruction in mathematics. As opposed to traditional mathematics, problem based instruction allows students to investigate and make sense of mathematics concepts without imposing a bunch of rules. Traditional mathematics focuses on rules and regulations instead of focusing on higher-order thinking. According to Pogrow (2004) many students rebel against mathematics because it is presented as rules and regulations. He goes on to state that many times, students do not dislike the mathematics, but the rules it poses. This causes them to become disengaged based on the delivery style not based on ability. Often times, the traditional method of teaching mathematics motivates students to care more about getting good grades than actually learning. In some cases, the traditional method is linked to cheating because students are so focused on getting a good grade (Pogrow, 2004). In these cases, students are not actually retaining or caring about the concepts they learn in mathematics because they do not relate to them.

Problem based instruction in mathematics is linked with a constructivist way of teaching. Polak (2008) stated that the constructivist approach “emphasizes the development of thinking skills through discovery learning” (Polak, 2008 p. 36). Polak also stated that in discovery learning, “students make connections between their work, peer work, and the world around them” (p. 36). This is where the development of higher-level thinking skills occurs. The constructivist approach is linked to students who want to learn the concepts in class because they see the everyday value of knowing the content. In these cases, students tend to retain the information because they find meaning in it outside of class.

Another positive effect of problem based instruction is the increase in student motivation. According to Luft, Brown, and Sutherin (2007) the United States uses mostly traditional curriculums that cover many concepts, but with little depth. Other countries that continually outperform the United States on international math tests use problem based instruction that is authentic and relevant to students’ lives. They use problems that develop skills and knowledge that will be useful in the students’ futures. These types of problems increase motivation, retention, and engagement.

Problem based instruction also has positive instructional effects. First, problem based instruction exposes students to all levels of Bloom’s taxonomy. Bloom (1956) stated that six levels of cognition exist. From basic to complex they include remembering, understanding, applying, analyzing, evaluating, and creating. Analyzing, evaluating, and creating can only be met when students attempt problems without given any strategies ahead of time. Most of the time, the traditional approach, teaches the students a skill and then gives them problems to practice. Usually the practice problems include a few word problems. It is common for teachers to think that these word problems address the higher levels of Blooms taxonomy, but they do not (Chamberlin, 2010). These word problems require skills taught in that lesson so they only reach the applying level. Chamberlin (2010) explained how the top levels of Blooms taxonomy can only be addressed when strategies and routines are not stated before students attempt a problem. Problem based instruction starts with a real life higher level word problem before the students learn any new skills. This causes the students to have to analyze and evaluate truths that they already know. It also causes students to have to think about what additional truths they need to understand the problem. This is where the teaching of that skill fits into the lesson creating a purpose for learning it.

Encouraging the use of 21st century skills is another positive effect of problem based instruction. The 21st century work environment requires people who can communicate, work together, and take risks in order to solve problems (Gasser, 2011). It is vital that students are given opportunities to work on this in the classroom. Gasser (2011) explained that through collaborative work time, students practice the ability to listen to others and to present their own ideas. Nelson and Sassi (2007) stated that while working on problem-solving strategies, students need to be given time to discuss their accuracy and effectiveness. Not giving time for discussion deprives students of the opportunity to use rigorous mathematical thinking. Overall, problem based instruction positively effects students' mathematical reasoning and supplies instruction that better prepares students for the 21st century work place.

Extensive research shows that problem based instruction positively effects student achievement in math. As the United States falls behind other countries on international math tests, educational systems are moving away from traditional practices and towards problem based instruction Cavangh, S. (2005). Teachers who implement problem based instruction successfully will more than likely see an increase in student achievement, motivation, risk taking, engagement, collaboration, and other 21st century skills. Students need to engage in a journey of learning that will truly prepare them for the future. Problem based instruction gives them this opportunity. Based on research, I decided to see what effect an authentic mathematics competition would have on student performance by advanced 6th grade learners.

Description of Research Process

The research process included a number of components. First, the research took place over a five week time period. On the first day of each week, all students were given 6 authentic math problems. Participation in the competition each week was encouraged but not mandatory. Students were allowed to work on the problems in and out of class independently throughout the week. They were given permission to work on the problems in class whenever they grasped the concepts from the daily lesson. This allowed them to be engaged in math problems while I helped students who needed extra support to understand the daily concepts.

The first data source used was my “Authentic Mathematics Competition Field Notes.” On the field notes, I recorded three pieces of information every day. First, I documented the learning target for each day. Next, I logged the fraction of students who chose to use class time to work on the problems each day. I recorded the learning target and fraction of students using class time because the daily learning target often affected the number of students who worked on challenge problems. For example, some days I taught concepts that were more difficult or brand new to the students. Fewer students attempted challenge problems on those days and I needed a way to note that. Last, I recorded which questions were answered correctly. The purpose of the breakdown was to be able to compare week to week. Matching the daily plans and learning targets with the breakdown helped me to notice reasons for higher or lower scores each week. For example, some weeks we had fewer days of mathematics because of MCA testing. Because I noted that, it will help me understand why fewer students used class time to work on challenge problems. Also, fewer days of math could affect the number of problems students got correct.

Challenge problems were also collected each week. At the end of each week, the problems were collected, graded, and recorded in an Excel spreadsheet. The students were given their scores at the beginning of the next week for review. An example of week one's problems have been included in Appendix B. The problems were then given back to the students at the beginning of the next week so they could see their scores. The scores were valuable information for me because they allowed me to analyze the scores of each student as well as compare scores of different students. This data source also proved useful for student motivation. I kept track of each student's overall score as the weeks progressed. Each Monday, I posted the scores of the top eight students in the classroom. I only posted eight scores because I did not want to negatively affect the self-esteem of students. Posting the top eight scores inspired competition between students. The students whose names were on the chart kept competing to try to pass each other. Some students whose names were not on the chart tried extra hard the next week so they could get their name on the chart.

My third data source was a student survey. First, the survey was completely anonymous. I wanted the students to feel full confidence that being honest on the survey would not impact their grades or how I perceive them. The student survey was given at the end of week two after they turned in their weekly challenge problems. It consisted of 10 questions. Eight of the questions were closed-ended and 2 were open-ended.

There were different purposes for the questions I asked. One question regarded gender. Other questions were about the number of challenge problems the students were getting correct and about whether they have attempted any. There was also a question about what score the students received on their last chapter test. Other questions asked how students felt about the level and number of problems each week. I also asked an open-ended question about ways to improve the competition. The purpose for this group of questions was for me to adjust the competition in a way that would improve it. After the survey was collected, I immediately examined the questions about ways to improve the competitions. This helped the next three weeks improve in a few ways. First, many students indicated on the survey that they would like more time in class to work on the challenge problems. Therefore, I structured the class time to include more chance for students to work on the challenge problems each day. Also, a few students recommended on the survey that I should write the correct answers while correcting the weekly problems. I took the suggestion and saw an immediate increase in interest when I handed back the graded weekly problems. As a result, the survey helped me improve the competition.

My final data source comprised of the chapter tests from our math curriculum. Prior to the math competition, we took nine tests throughout the school year. During the competition we took three tests. I planned to compare the tests that we took before the competition to those we took afterwards. On all tests, a grade of one, two, three, or four was given based on the number of problems each student got correct. On most chapter tests the following criteria was used: 4=92-100%; 3=80-91%; 2=60-79; 1=below 60%. Using the chapter test allowed me to see how the competition affected student performance. Chapter tests consisted of different skills that aligned with the seventh grade math standards. For example, we took the tests for chapters 11, 12, and 13 during the weeks of the competition. These skills included measurement and area, surface area and volume, and probability. These are all 7th grade standard skills.

The overall math competition took five weeks. There were five sets of problems. Each set had six problems. At the beginning of the competition, I told the students that prizes would be given to students who come in first, second and third place at the end of the five weeks. At the beginning of each week a number of students would hurry into the mathematics classroom to see the standings. Many students challenged themselves with realistic expectations. There were five students who were legitimately contenders for first place throughout the whole five weeks. Other students stayed engaged because they wanted to be on the chart for the final standings.

To summarize, four data sources were used during the research process. They included a field notes, challenge problem results, a student survey, and chapter tests. All four of these sources were used to determine what effect the authentic mathematics competition had on advanced 6th grade students. The next step was to analyze each of the data sources.

Analysis of Data

Four sources of data were analyzed during my research. They included field notes, the challenge competition problems, a student survey, and chapter tests. There were some significant trends found through the data analysis process.

After the action research field work was complete, I analyzed the data. First, I viewed the actual competition results. The competition had five weeks of data to analyze. I kept track of each student's scores for all five weeks and compiled the total score for the entire competition. Next, I found the mean of the entire class for each of the five weeks. The main piece of information that stood out was that the week one class average was 3.1 and then the scores dipped until week 5 where it rebounded 1.44 (see Figure 1).

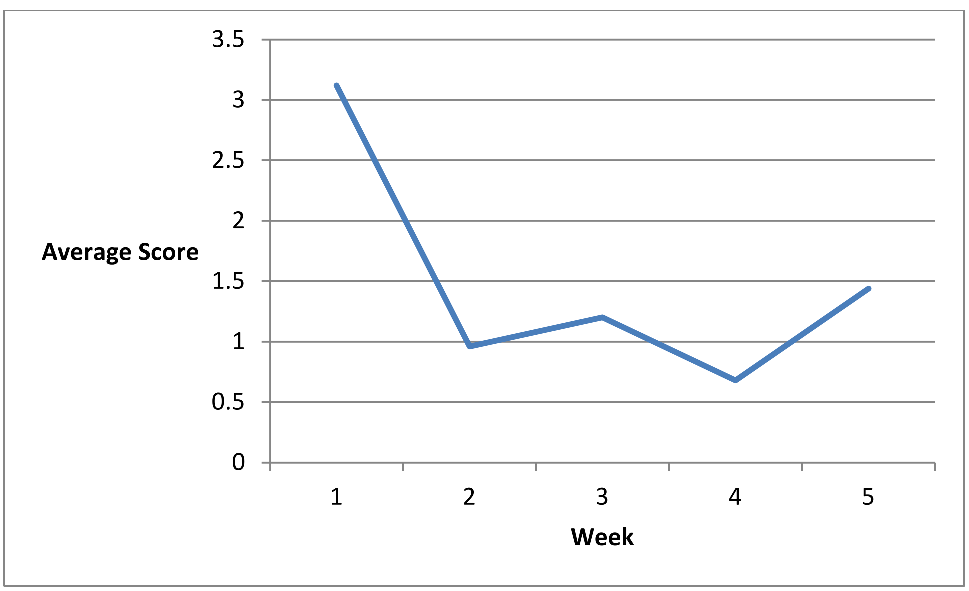


Figure 1. Math competition results (whole class).

I then broke the same data down into categories. First, I found the average weekly competition results of the top eight competition finishers as compared the bottom 8 finishers. These data showed that although the top eight had a much higher average, they still dropped after week one and then had an overall increase in week five (see Figure 2).

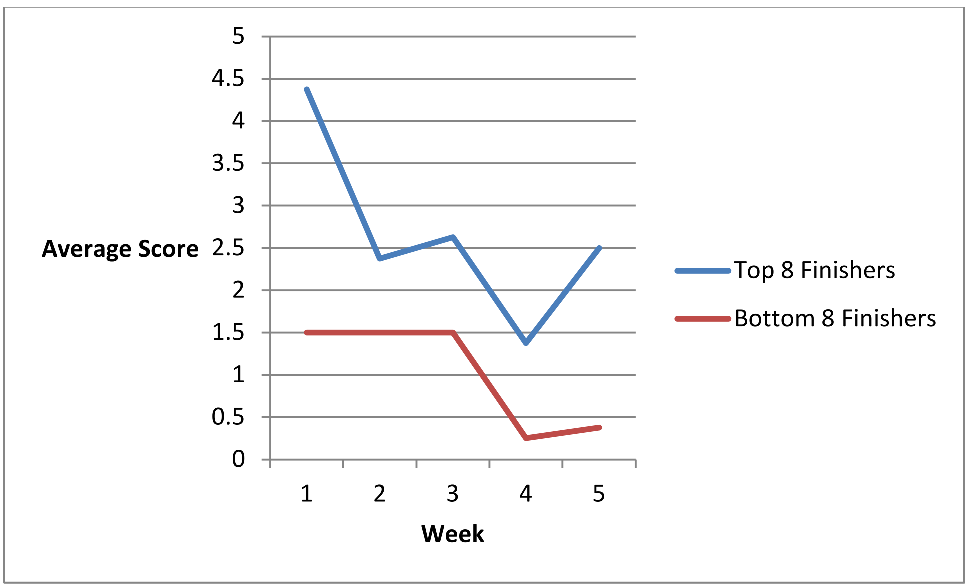


Figure 2. Math competition results.

I did one more breakdown of the competition data to see if any subgroup broke the pattern of the first two. Next, I broke the data down by gender. Fifteen boys and ten girls participated in the math competition. As I compared the weekly average of boys and girls, I discovered that there was not much difference between the genders. I also discovered that both boys and girls did best in week one and then dipped. They both had a small increase in success in week five (see Figure 3).

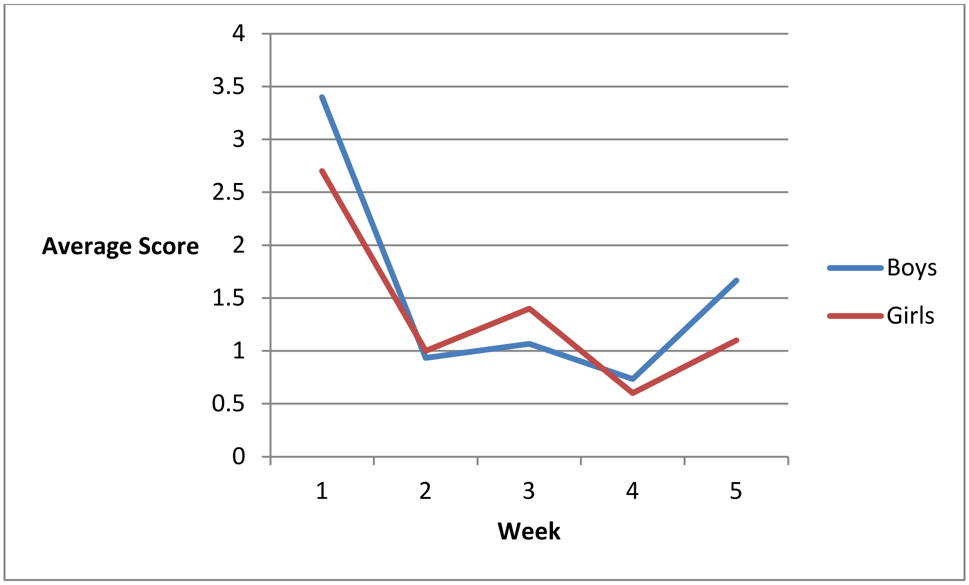


Figure 3. Math competition results (boys and girls)

Next, I analyzed the chapter test results. For this, I recorded the chapter test grades for the 10 tests taken before the competition. I then recorded the test grades for the 3 tests taken during the competition. All test grades were based on a 1, 2, 3, 4 grading scale. Then, I calculated the mean, median, and mode of each of the 13 tests. (see Figure 4).

Breaking the data down like in Table 1 allowed me to analyze the tests that were taken before the competition and compare them to the tests taken during the competition. I first used the data from the whole class. The overall mean grade of the 10 tests taken before the competition was 2.78. The overall mean grade of the 3 tests taken during the competition was 3.12. Therefore, the overall average grade was higher for the tests taken during the competition (see Figure 4).

Table 1

Mean, Median, and Mode of All Chapter Tests

	Chapter Test Grades Before Competition										Chapter Test Grades During Competiti		
Student	**Chapter 1 Test**	**Chapter 2 Test**	**Chapter 3 Test**	**Chapter 4 Test**	**Chapter 5 Test**	**Chapter 6 Test**	**Chapter 7 Test**	**Chapter 8 Test**	**Chapter 9 Test**	**Chapter 10 Test**	**Chapter 11 Test**	**Chapter 12 Test**	**Chapter 13 Test**
Mean	2.68	2.52	2.52	3.04	2.88	2.76	2.52	3.12	2.72	3.08	3.12	2.96	3.28
Median	3.00	3.00	2.00	3.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00
Mode	3.00	3.00	2.00	4.00	3.00	3.00	2.00	3.00	2.00	3.00	3.00	2.00	4.00

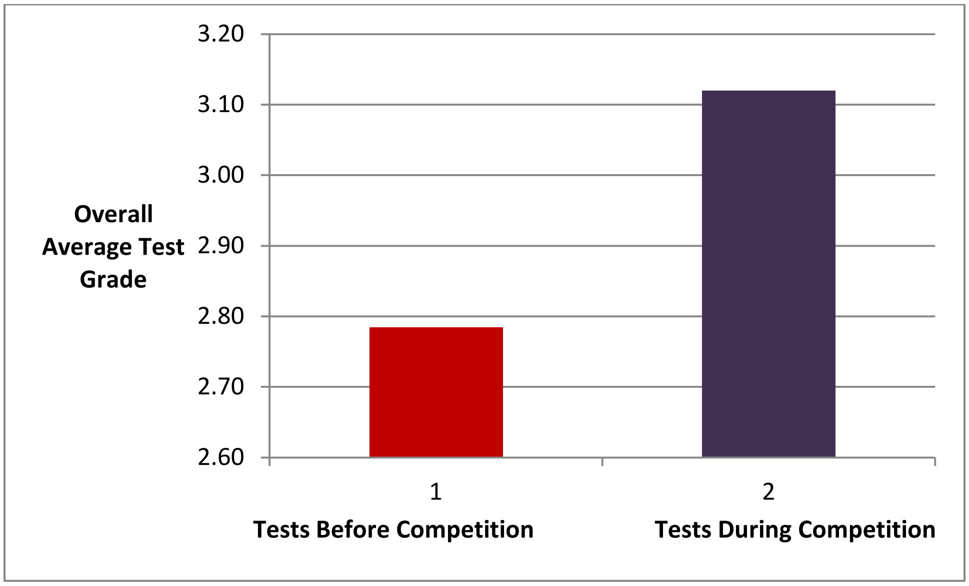


Figure 4. Average test grades (whole class).

Looking at the whole class's data, I then compared the mean number of 4's on tests before the competition with the tests taken during the competition (see Figure 5). The mean number of 4's was 5.20 on tests before the competition and 9.00 on tests during the competition. Therefore, on average, the class had more 4's on tests taken during the competition than on tests taken before the competition.

Then I compared the mean number of 1's and 2's on tests taken before the competition with tests taken during the competition (see Figure 6). The mean number of 1's and 2's before the competition was 10.10. During the competition, the mean number of 1's and 2's was 6.67. Therefore, on average the class had fewer grades of 1's and 2's during the competition than on tests before the competition.

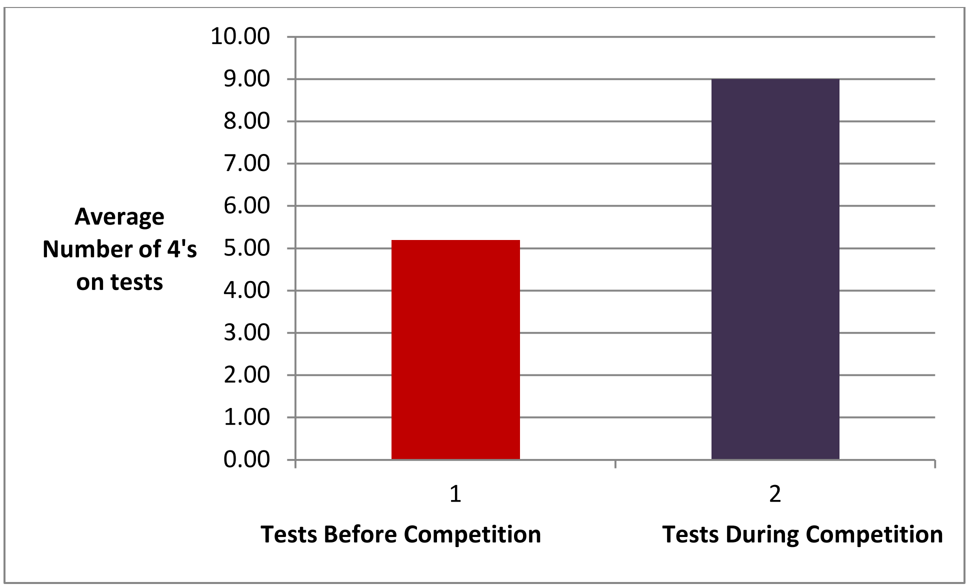


Figure 5. Frequency of 4's on tests (whole class).

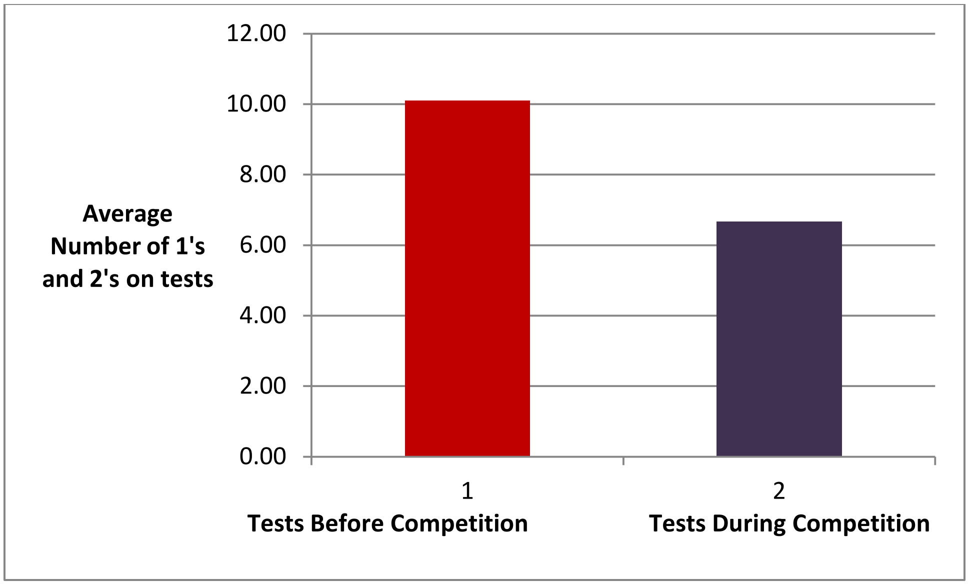


Figure 6. Frequency of 1's and 2's on tests (whole class).

After viewing the above data, I wanted to see if the classes' average grade improvement was a result of the competition. It could be argued that the 3 tests taken during the weeks of the competition were easier tests. If the 3 tests taken during the competition were easier, then almost all students' grades should have improved. Therefore, I analyzed the chapter test data of students who finished in the top 8 in the competition. I selected the top 8 finishers, because they were the most successful and engaged in the competition. Therefore, I compared the top 8 finishers' mean test scores, mean number of 4's, and mean number of 1's and 2's on tests before the competition to tests taken during the competition (see Figures 7, 8, and 9). In all 3 categories that I analyzed, on average the top 8 finishers made important gains on tests taken during the math challenge competition.

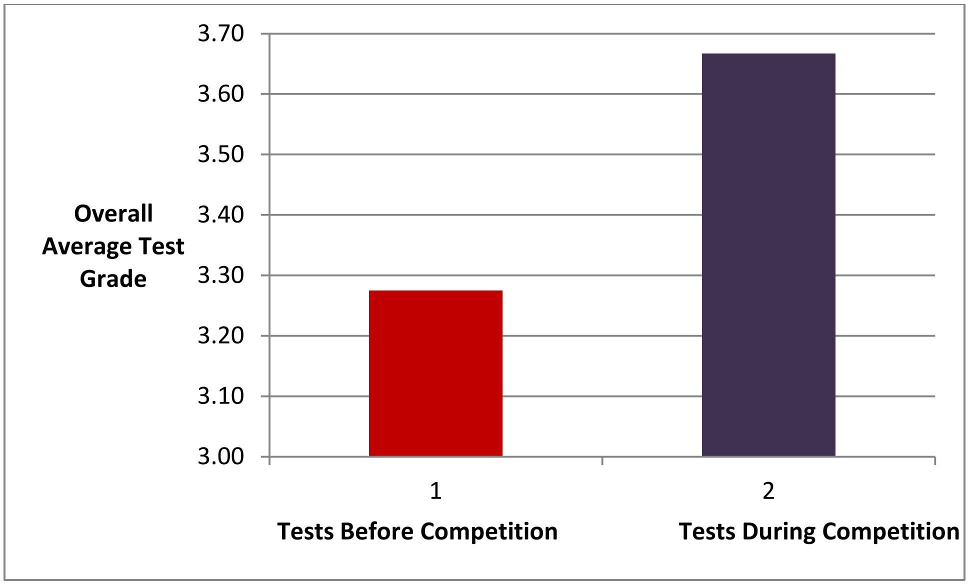


Figure 7. Average test grades (top 8).

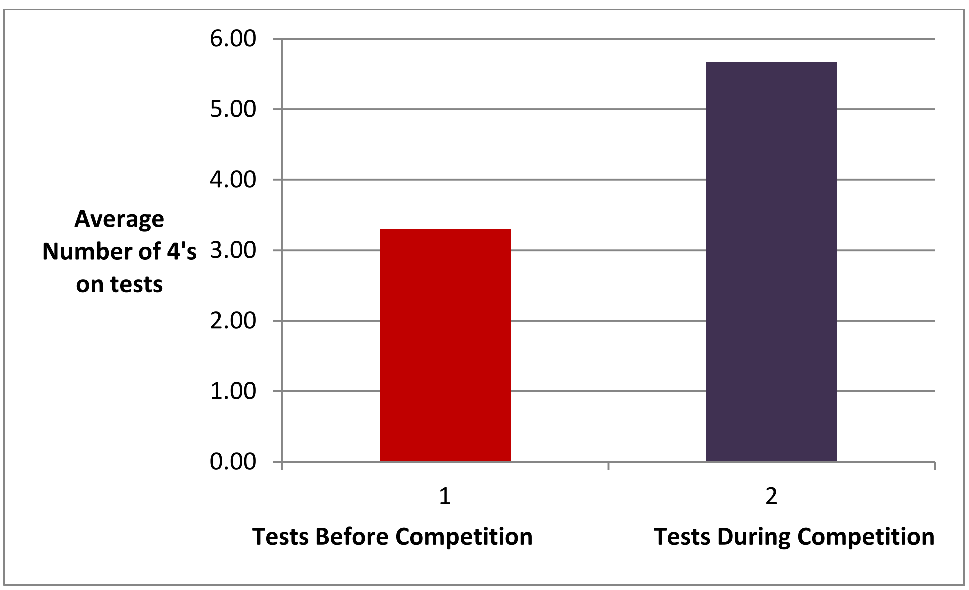


Figure 8. Frequency of 4's on tests (top 8).

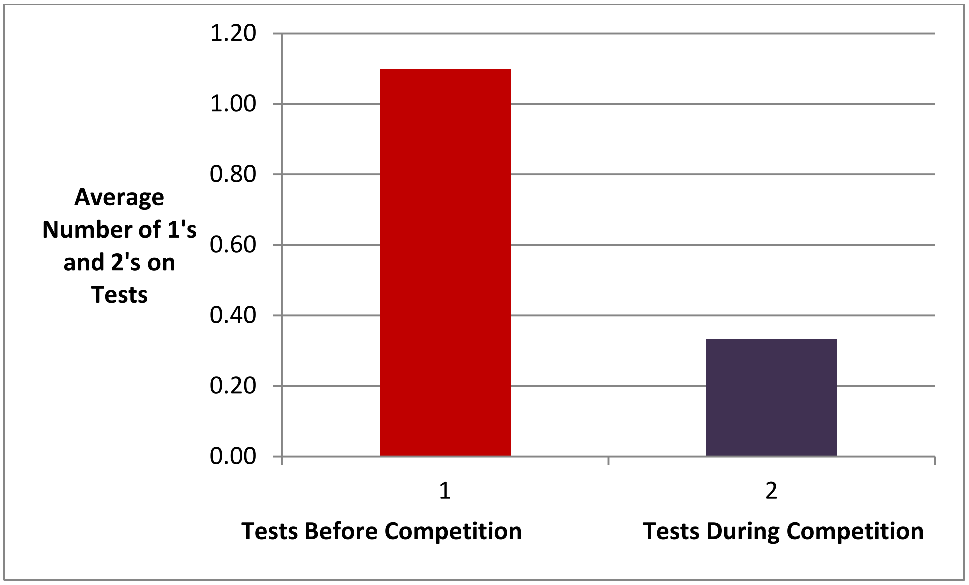


Figure 9. Frequency of 1’s and 2’s on tests (top 8).

Next, I did the same analysis with the bottom 8 finishers in the competition. These 8 students were the least successful and engaged in the competition. I calculated the mean test scores, mean number of 4’s and mean number of 1’s and 2’s on tests before the competition and tests during the competition (see Figures 11, 12, and 13). These data reveal that on average, students who struggled with the competition made minimal gains on test that were taken during the competition. They also showed minimal gains in average number of 4’s and actually scored more 1’s and 2’s on tests taken during the competition. Therefore, there was a direct relationship between students’ success in the competition and improved chapter test scores during the five weeks of the competition.

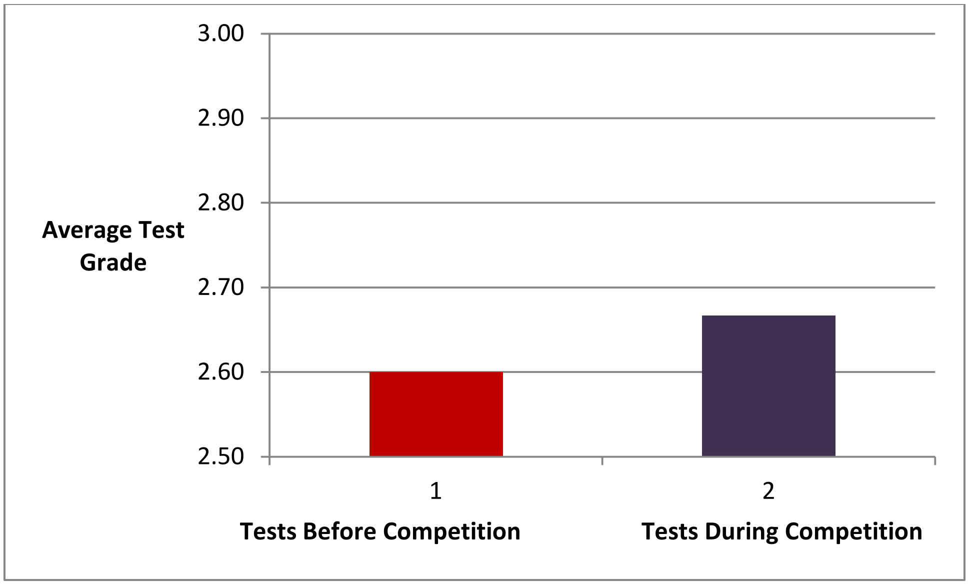


Figure 10. Average test grades (bottom 8).

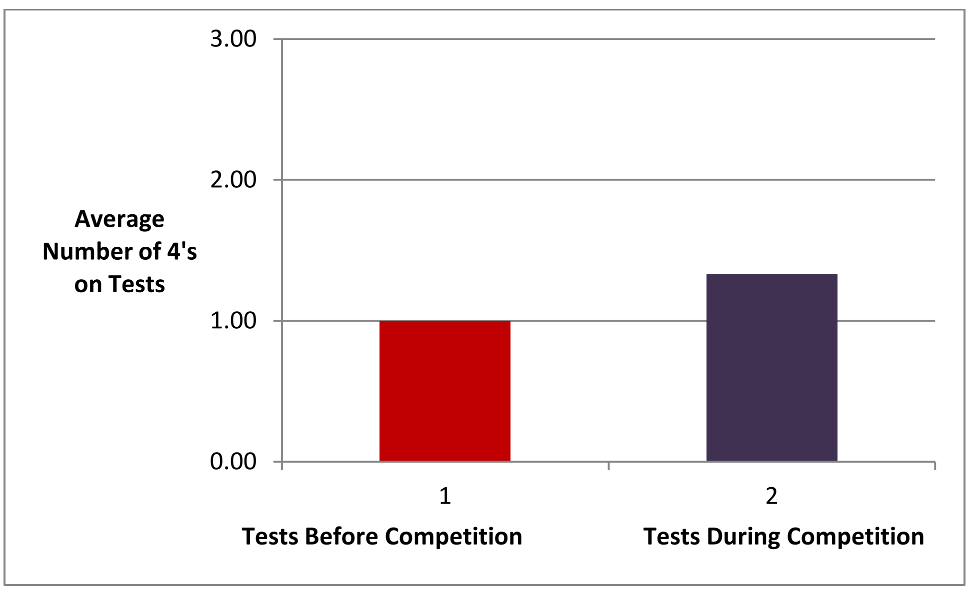


Figure 11. Frequency of 4's on tests (bottom 8).

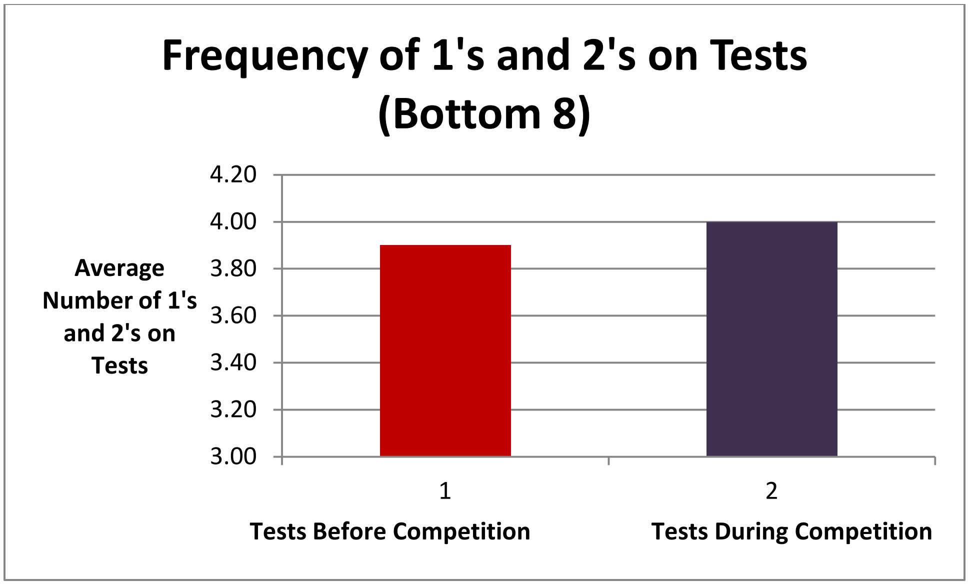


Figure 12. Frequency of 1’s and 2’s on tests (bottom 8).

Next, I analyzed the results from the field notes. The purpose of field notes was to see if using class time affected the weekly competition scores. Each day, I recorded the percent of students who used class time to work on their challenge problems. I then calculated the overall percentage of students using class time for the entire week and compared it to the mean scores of each week. As I analyzed the results, I noticed that time spent in class had little or no relationship to the weekly scores (see Table 2). Some weeks had a higher percentage of students using class time, but had lower average competition scores. Looking at this data, I also noticed a large fluctuation each week of class time usage. The fluctuation was due to many outside factors. Some days, the lessons were more challenging and students gave more time to grasping the daily lesson. Other days, we had a shortened math class because of MCA and MAP testing. These factors heavily influenced the number of students who used class time to work on challenge problems. However, I did see a common theme among the most advanced students. The top three students in the class consistently pushed themselves to grasp the daily concepts so they could use their time to work on the challenge problems.

Table 2

Effect of Class Time on Competition Performance

Week	Percentage of Students Using Class Time to Work on Challenge Problems	Mean Competition Score
1	40%	3.12
2	23%	.96
3	3%	1.20
4	63%	.68
5	19%	1.44

Last, I analyzed the student survey. The purpose of the survey was to see if students enjoyed the competition. On the survey, students were asked about their involvement in the competition. They were also asked if the competition made math more fun (see Table 3). The results were overwhelming. 22 out of 25 students said that they at least attempted the challenge problem competition during the previous week. This tells me that students were at least motivated to give the problems a chance each week. 24 out of 25 students stated that the math competition made math be more fun.

Table 3

Participation in Challenge Problem Competition

Survey Question	Yes	No
Did you try any of the challenge questions last week?	88%	12%
Does the challenge problem competition make math more fun?	96%	4%

In conclusion, the results show the effect that authentic mathematics competitions have on the performance of advanced 6^{th} grade students. In reaction to the research, I will make changes to my teaching practice in mathematics. The next section will explain in detail what I will do from this point.

Action Plan

The action research project showed me the importance of keeping the advanced math students engaged every day. The competition gave advanced math students a reason to be excited about mathematics. As the students became excited about the competition, they became more engaged in daily lessons. Therefore, the competition did in fact improve the performance of advanced of advanced sixth grade learners.

The findings of my action research have great meaning to my practice. First, the results show that advanced math students perform better on chapter tests when they have been challenged each day. The challenge does not even have to be connected to the current chapter or daily lesson. As long as advanced students are given the opportunity to use higher order thinking skills each day, their performance will improve. In my case, the challenge problems had nothing to do with our daily learning target. Students were given permission to work on challenge problems once they mastered the daily learning target. I saw students become more enthused about the daily learning targets because they wanted to work on the challenge problems.

Before the competition, many advanced math students in my class were bored because they were not challenged daily. They would often day dream during the daily lesson because they knew it would just be a step-by step procedure on how to do a skill. They were not given the opportunity to use their skills in new situations. Within a month, the advanced math students were not performing to their potential. This same problem has occurred every year in my math class. Therefore, the results of my action research mean that I need to change my teaching practices in math class.

My future teaching practice will consist of problem based instruction as opposed to the traditional approach. As I observed the mathematics competition, I noticed advanced math students became engaged in math each day. I do not believe it was specifically the competition that improved performance. The advanced math students' improvement appeared to be the result of being challenged each day. Therefore, my teaching practice must include daily planning for challenging advanced students.

Changing to a problem-based instruction approach will include a number of changes. First, I will need to start each lesson by giving a challenging problem that includes the daily learning target. I will give all students in the class a chance to solve the problem without getting help. Next, students who get the problem correct will do more advanced problems. These students do not need to be shown how to do the daily target. They need to be given a chance to apply what they know to more challenging problems. Meanwhile, students who struggle with the first problems will receive guidance on the daily learning target. Instead of planning each lesson step by step, I will prepare numerous problems at different levels of difficulty. I will monitor and adjust each lesson to match the students' needs. Overall, the problem-based instruction approach will give all students the opportunity to be challenged at the appropriate level every day.

The research will have several possible impacts on student learning. First, the competition increased the performance of advanced students. Therefore, I will plan to have at least two competitions each year. One competition will take place around November and the other one in February. The competition for research took place in May which was impacted by standardized testing. I believe that having two competitions will be fun and engaging for all math students which will affect performance for the better. The research will also impact student learning because it has changed my focus. From now on, my math students will approach math problems using higher-order thinking instead of trying to use memorized steps and procedures. Hopefully, this will help the advanced students be excited and challenged throughout the year. I think this will help advanced students reach their full potential as I saw during the research. To summarize, having two math competitions and changing my teaching practice will hopefully help all math students be more challenged and engaged.

Conducting this research has given me an idea for a potential future action research investigation. During this research, I noticed that most sixth grade math students become disengaged when they are given too many rules or procedures. I also observed that many sixth grade students prefer to be given a chance to solve problems on their own first. Then, if they get stuck, they are ready to receive specific instruction to help bridge the gap. Furthermore, I have seen students learn skills and perform well on a tests, but forget the skills within a few weeks.

Therefore, a potential action research investigation will be to see if one "Monster Math" problem each day will help sixth grade math students become excited about learning new math skills. I will also see if the "Monster Math" problem helps students retain skills they have learned. The "Monster Math" problem will require students to use the order of operations to solve large math problems. These problems will include adding, subtracting, multiplying, dividing, integers, fractions, decimals, exponents, factorials, parentheses, and other math components. My hope is that students will become motivated to successfully complete the "Monster Math" problem each day. Then, the skills we learn throughout the year will give students an advantage on the "Monster Math" problems. Hopefully, this will inspire students to want to learn the skills each day. Also, the "Monster Math" problems will give students a chance to review skills they have learned earlier in the year. Hopefully this will help students retain the skills they learn. In conclusion, my research has inspired potential future investigations.

References

Bloom, B, S, (Ed,). (1956). *Taxonomy of educational objectives, the classification of educational goals* - Handbook I: Cognitive domain. NewYork,NY:McKay.

Cavangh, S. (2005). Poor math scores on world stage trouble U.S. *Education Week, 24* 16), 1-18.

Chamberlin, S. A. (2010). Mathematical problems that optimize learning for academically advanced students in grades K-6. *Journal of Advanced Academics, 22*(1), 52-76,168.

Dennis, J. & O'Hair M, J. (2010). Overcoming obstacles in using authentic instruction: A comparative case study of highs school math & science teachers. *American Secondary Education, 38*(2), 4-22.

Ellett, C. D., & Monsaas, J. (2011). Development and validation of a new measure of teacher perceptions of science and mathematics learning environments. *Learning Environments Research*, *14*(2), 91-107.

Erickson, D. K. (1999). A problem-based approach to mathematics instruction. *The Mathematics Teacher, 92*(6), 516-521.

Gasser, K. W. (2011). Five ideas for 21st century math classrooms. *American Secondary Education*, *39*(3), 108-116.

Luft, P., Brown, C. M., & Sutherin, L. J. (2007). Are you and your students bored with the benchmarks? Sinking under the standards? Then transform your teaching through transition! *Teaching Exceptional Children, 39*(6), 39-46.

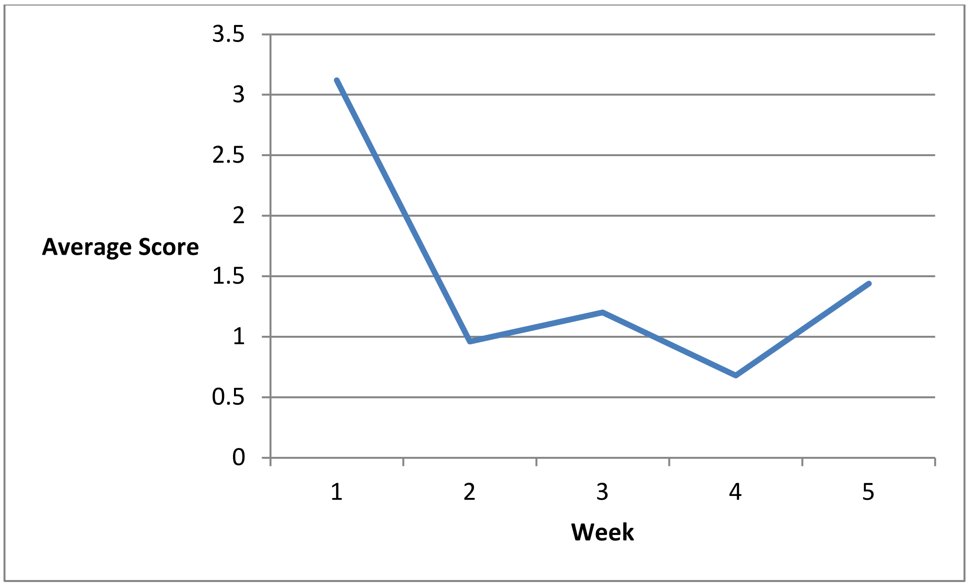
Nelson, B. S., & Sassi, A. (2007). What math teachers need most. *The Education Digest*, *72*(6), 54-56.

Pogrow, S. (2004). Supermath: An alternative approach to improving math performance in grades 4 through 9. *Phi Delta Kappan*, *86*(4), 297-303.

Polak, M. (2008). Using constructivist math methods in the everyday elementary classroom. *ProQuest Dissertations and Theses*, , 241, Retrieved from http://search.proquest.com/docview/304403680?accountid=26879

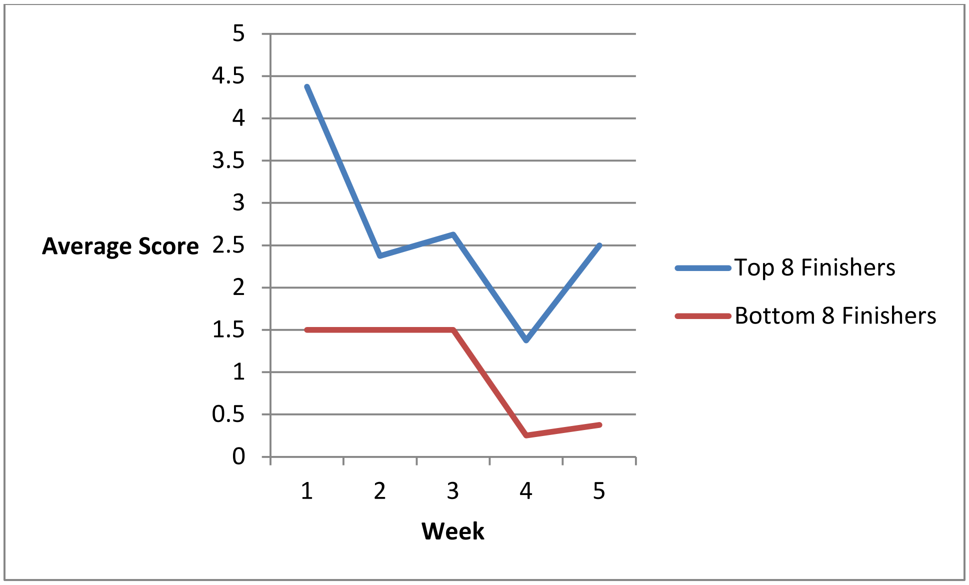
Appendix A

Math Competition Results (whole class)



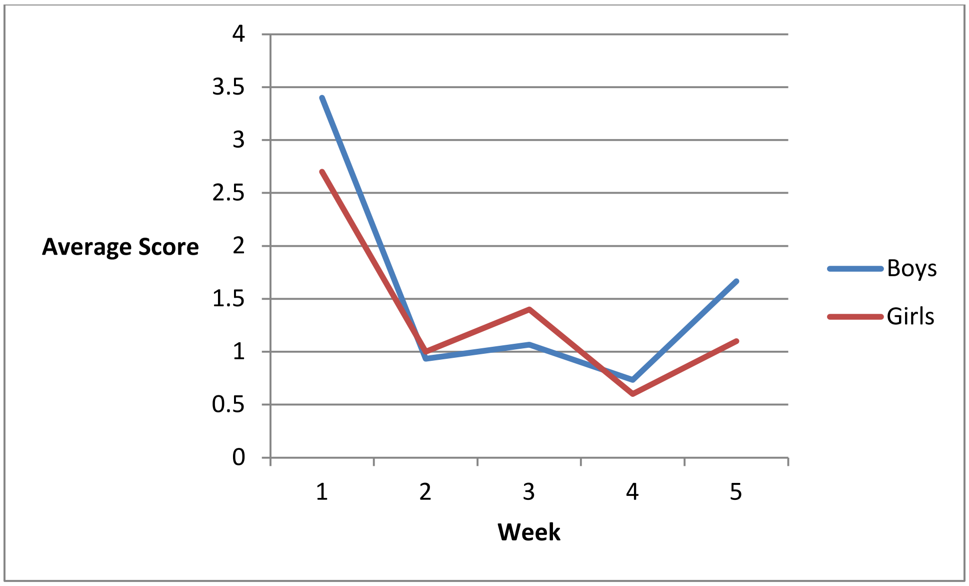
Appendix B

Math Competition Results



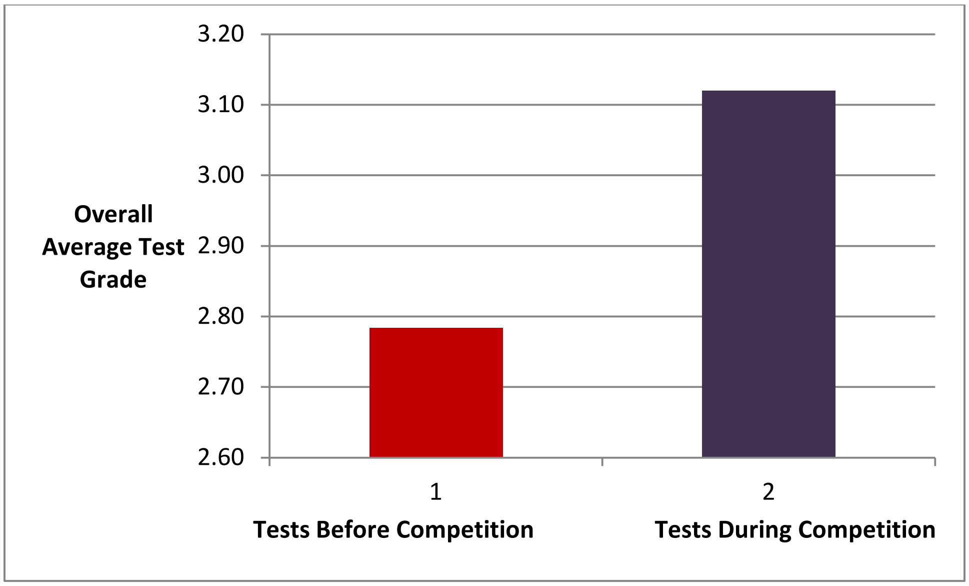
Appendix C

Math Competition Results (boys and girls)



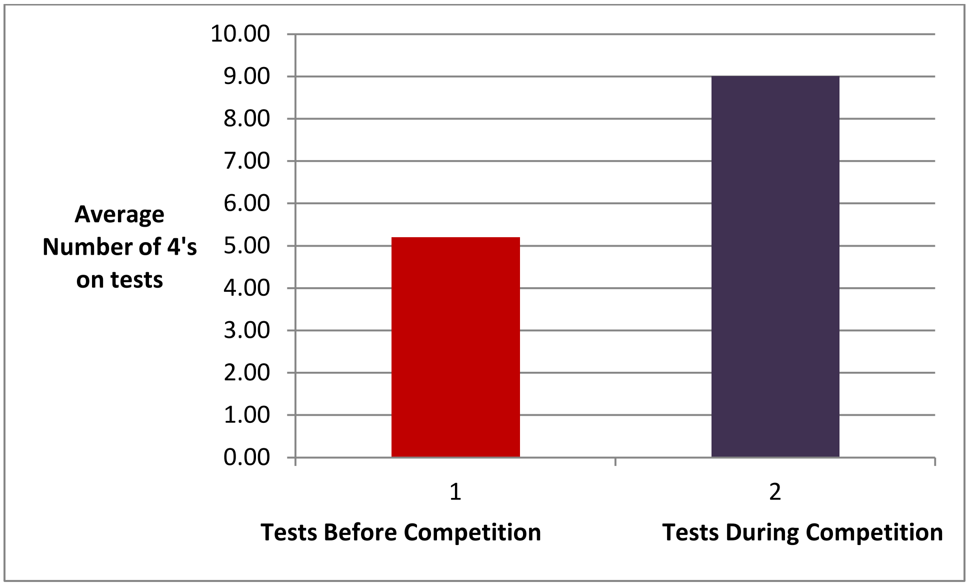
Appendix D

Average Test Grades (whole class)



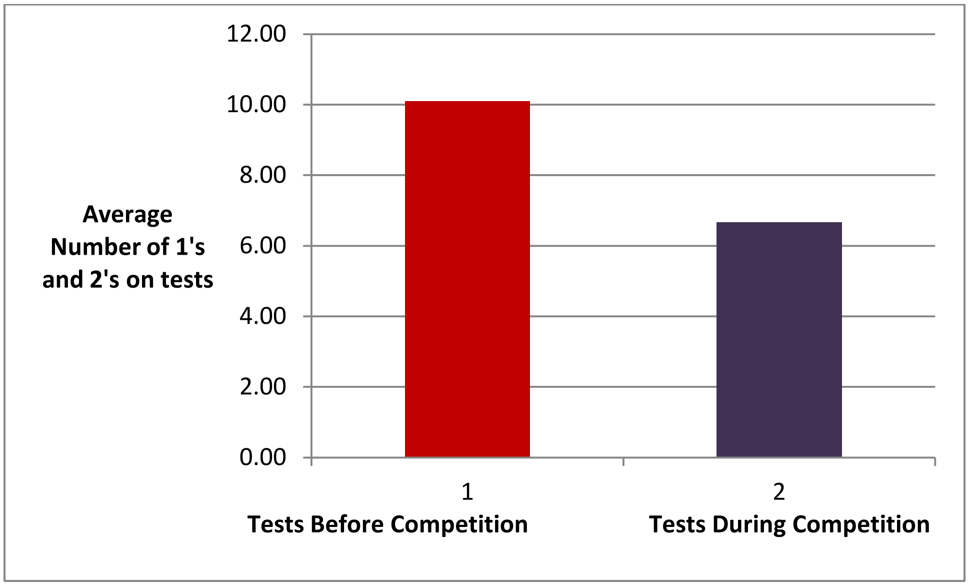
Appendix E

Frequency of 4’s on Tests (whole class)



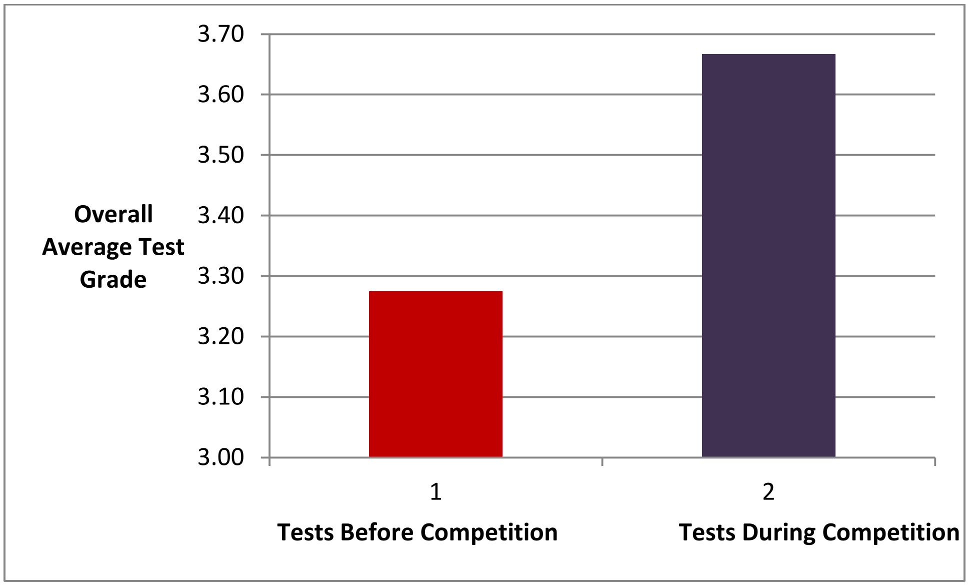
Appendix F

Frequency of 1’s and 2’s on Tests (whole class)



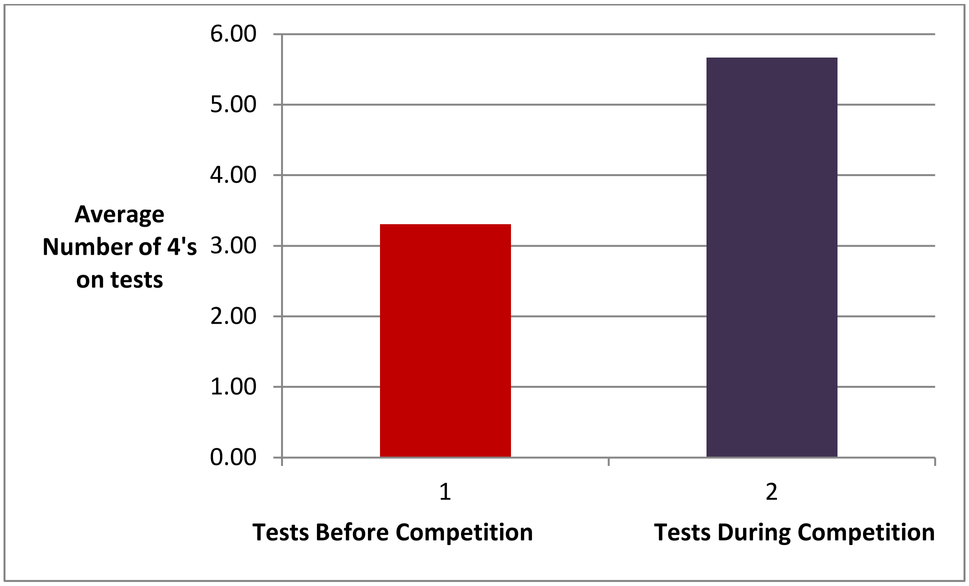
Appendix G

Average Test Grades (top 8)



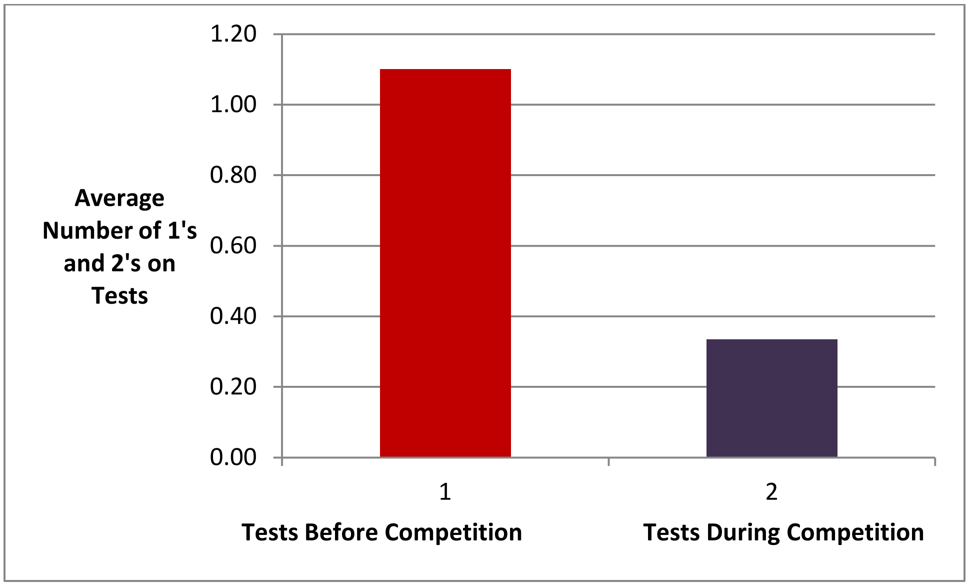
Appendix H

Frequency of 4’s on Tests (top 8)



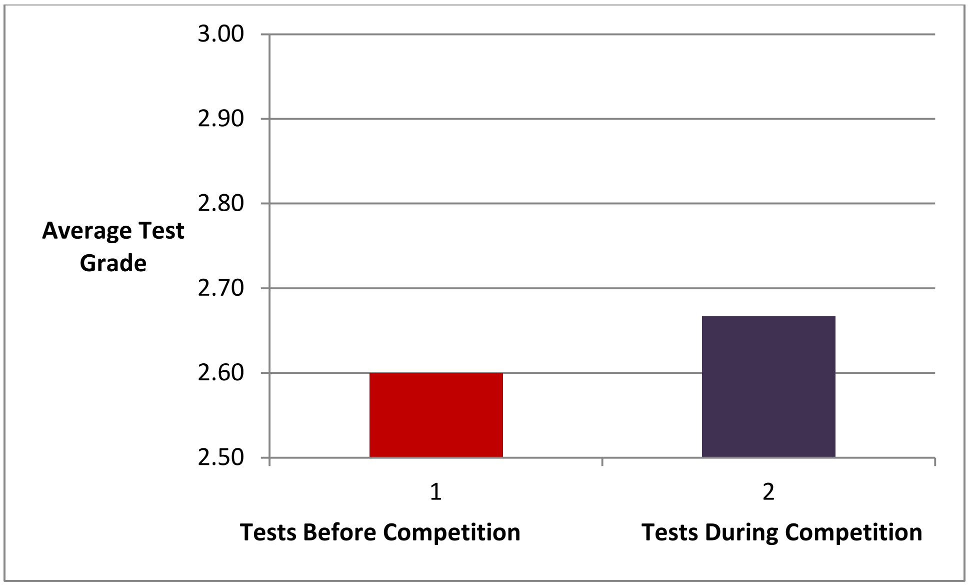
Appendix I

Frequency of 1’s and 2’s on Tests (top 8)



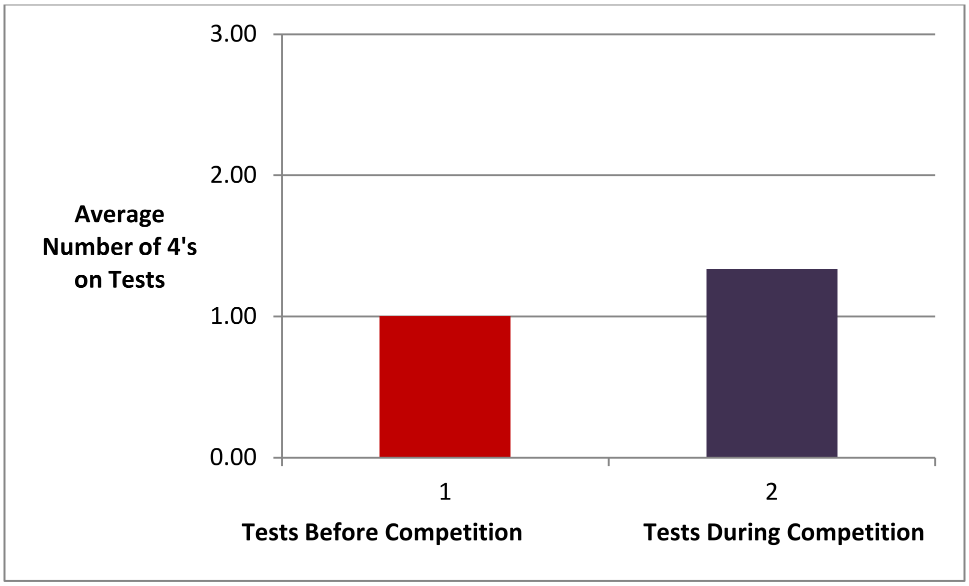
Appendix J

Average Test Grades (bottom 8)



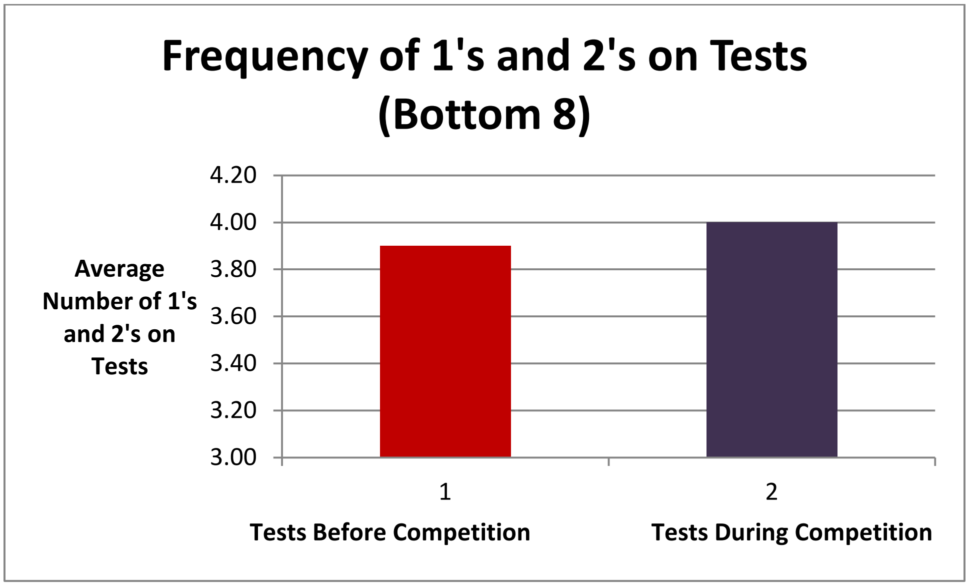
Appendix K

Frequency of 4's on Tests (bottom 8)



Appendix L

Frequency of 1's and 2's on Tests (bottom 8)



Appendix M

Mean, Median, and Mode of All Chapter Tests

	Chapter Test Grades Before Competition										Chapter Test Grades During Competition		
Student	Chapter 1 Test	Chapter 2 Test	Chapter 3 Test	Chapter 4 Test	Chapter 5 Test	Chapter 6 Test	Chapter 7 Test	Chapter 8 Test	Chapter 9 Test	Chapter 10 Test	Chapter 11 Test	Chapter 12 Test	Chapter 13 Test
Mean	2.68	2.52	2.52	3.04	2.88	2.76	2.52	3.12	2.72	3.08	3.12	2.96	3.28
Median	3.00	3.00	2.00	3.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00
Mode	3.00	3.00	2.00	4.00	3.00	3.00	2.00	3.00	2.00	3.00	3.00	2.00	4.00

Appendix N

Effect of Class Time on Competition Performance

Week	Percentage of Students Using Class Time to Work on Challenge Problems	Mean Competition Score
1	40%	3.12
2	23%	.96
3	3%	1.20
4	63%	.68
5	19%	1.44

Appendix O

Participation in Challenge Problem Competition

Survey Question	Yes	No
Did you try any of the challenge questions last week?	88%	12%
Does the challenge problem competition make math more fun?	96%	4%