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Calculators in the Classroom: Help or Hindrance?

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Action Research Project Report

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University of Nebraska-Lincoln
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Calculators in the Classroom: Help or Hindrance?

Abstract

In a world where technology is ever present and ever changing, is too much technology at too young of an age detrimental to a child's educational success? The purpose of this paper is to share the results of a four-month study that focused on the use of calculators in grade eight. This study was conducted in an eighth grade class, in a small kindergarten through twelfth grade school. This paper will share the findings of a study of a classroom in which calculator use was limited and mental computation was emphasized. The main focus of this study was whether or not there would be any improvement in the computation skills of my students and how, or if, their problem solving would be affected. As a result of this research project, I plan to permanently limit calculator use in grades seven and eight, as well as to implement a computational review that will be conducted yearly with all of my classes.

The most elaborate building will never stand if its base and support structure aren't strong enough to support it. The same can be said when it comes to a child's mathematics education. If a student doesn't have a strong base, it is very difficult, if not impossible, to understand the complexities of upper level mathematics. That being said, there are some tools that can help the student who understands the concepts but struggles to remember his or her times tables or who makes careless errors in the division algorithm. If these tools exist, shouldn't they be utilized?

Prior to this research project I permitted all of my students in grades seven through twelve to use scientific and/or graphing calculators. I believed, from personal experience, that the students would only use calculators to help them speed up their learning process, and I didn't feel a dependency would be formed. I hoped it would give the struggling students a boost so that they could catch up with their peers or at least have a chance to understand the more profound topics. I never believed I was doing any harm, until a parent approached me at a conference. She was concerned that her student was losing all of his prior skills in mathematics because I permitted unrestricted calculator use in my classroom. I assured her that this was not the case, and believed this was the truth.

In May of last year, when my school received achievement test scores, I did notice that our scores were lower for the portion of the test where calculators were not permitted. I was surprised to say the least. In seventh and eighth grade, I cover a great deal of topics designed to help students make good decisions, such as divisibility rules, reducing by factors, and the reasonableness of an answer. I teach them the rules, and, perhaps naively, believe that they will rely on them and use a calculator only when time and difficulty necessitate it. I also seldom use a calculator when I am working through a problem in a class discussion. I assumed they would follow my example.

What do I want to happen? I want my students to retain their prior mathematical knowledge. I want my students to choose to think for themselves, and not mindlessly push buttons on their calculator. I want students to use technology as a tool to broaden their knowledge base, not a crutch to stabilize a weak foundation. I also want students to become confident in their ability to solve a problem without technology.

What is the intervention? I plan to limit the use of calculators in my lower level classes (7^{th}, 8^{th}, and Algebra I). I also plan to emphasize the need to show all of the work necessary to obtain an answer. In this manner even if calculators are used, the thought process will be apparent.

Why is this important? If students do not truly comprehend the basics, it will be difficult, if not impossible, to build the abstract concepts that are necessary in upper level math classes. Students need to build confidence in their math ability, and if they are entirely dependent on technology, I fear this will never happen. This study will hopefully reveal if technology is a benefit or a barrier to middle level math students.

Problem Statement

The purpose of my project is to uncover the effect that technology has on student learning, specifically the effect of permitting calculators in grades seven and eight. I will be examining the variability of the number of students that show improvement on the standardized test (Terra Nova), the number of students that become confident in their ability to solve a problem without technology, and the number of students who retain prior mathematical knowledge.

I believe this project is worthy of consideration because it will help to resolve the age-old debate about calculators in the classroom. Is a calculator a helpful tool that frees the student to spend more of his or her time problem solving, or is it merely an excuse for a student to forget

everything he or she was taught? Everyone has an opinion on this matter, and I hope to give the reader enough information to make an informed decision as to how this pertains to middle school students.

Literature Review

I am a technology aficionado. I love all of the latest toys, and I enjoy utilizing them in my classroom. Besides the scientific calculator, my students have been exposed to graphing calculators and Probes, Geometer Sketchpad, Power Point, the Web and anything else on which I can get my hands. The students really enjoy the break from paper and pencil, are engaged in the learning process, and seem to learn a great deal from the exposure.

So, what's the problem? Last year at parent-teachers conference, I had a parent accuse me of using too much technology. She insisted that I should be focusing on the basics, asserting that her son (an eighth grader) no longer knew his multiplication facts, or the division algorithm. Admittedly these are not topics on which I spend time, because they are thoroughly covered at the elementary level. When I got achievement test results back last spring, however, I was surprised at how low our scores were for the section of the test where the students were not permitted to use calculators. Perhaps this parent was right. By giving students permission to use calculators, am I giving them permission to forget what they have learned? It is for this reason that I chose calculator usage as my problem of practice.

As I began researching this problem, I turned first to the National Council of Teachers of Mathematics' (NCTM) (2000) Principles and Standards for School Mathematics. NCTM supports the advancement of technology in the classroom, and asserts that the use of technology often allows for problem solving to occur in greater depth. It also acknowledges that the overarching principle of learning requires students to actively learn with understanding and build

new knowledge from experience and prior knowledge. Although my students are actively engaged in the learning process, I am concerned that they are losing their grip on vital prior knowledge. New knowledge is, after all, built on a basis of pre-existing ideas, according to Bazzini (2002) in her study of teaching experiments based on body-related metaphors. In my study I hope to uncover whether or not my students are retaining the foundation that was built in elementary school.

My next step was to turn to research. The first question I tried to answer while sifting through educational journals was, "What effect will limiting calculator usage have on student achievement?" This was a daunting task. Because the NCTM supports technology usage, most of the journals found calculators to be a positive force in the classroom. Even in very young students, calculator usage can be seen as a positive. In an article by Thom and Pirie (2002), a group of third grade students were given an involved volume problem. These students were required to construct a box (without a top) from a piece of cardboard that would hold the most linking cubes. The students would create a number of boxes and eventually appeared to grasp the concept of volume. The task required a great deal of problem solving on the students' part, and at one point in the process one small group became frustrated after attempting a long string of repeated addition. The authors comment on the fact that the students' frustration and impatience could have been alleviated if a calculator would have been available (Thom & Pirie, 2002, p. 16). Clearly the integrity of the problem wouldn't have been challenged by the presence of a calculator, and maybe the uniqueness of the task is the key. Nowhere in the article does it suggest that these students used calculators on a regular basis.

In another article. Bridgeman, Harvey, and Braswell (1995) wanted to see if using a calculator on a standardized test had an effect on mathematical reasoning. Bridgeman, Harvey,

and Braswell studied a sample of college-bound juniors from two hundred and seventy-five high schools who took a test which consisted of 70 math questions from the SAT. Half of the students were permitted to use calculators, and the other half were not based on random selection. Their study appeared to demonstrate that the use of calculators on a standardized test resulted in a modest increase in test scores. I also found it interesting that the students who used calculators in this study required the same amount of time to complete the test as the students who were not permitted to use them on the test (Bridgeman, Harvey & Braswell, 1995, p. 323-340). Time is one of the reasons that I have always allowed my students to use calculators. Perhaps this is a misconception on my part, or perhaps it depends on the problems given. These problems may have required more depth of thought, and maybe I give too many problems that focus on calculation.

I was able to find one article that dealt to some degree with the idea of limiting calculator usage. The article by Kilpatrick (2001) tried to synthesize the literature on mathematics learning and provide research-based recommendations. In the article, in an attempt to define the term "fuzzy math," Lynne Cheney, wife of the current vice-president of the United States, is quoted as criticizing NCTM for introducing into the schools "fuzzy math." By this she meant instruction that down-plays computational skills, advocates cooperative learning and technology, and promotes the view that getting the right answer to a math problem can be much less important than having a good rationale for a wrong one (Kilpatrick, 2001, p.102). Her comments really seemed unsettling to me, primarily because I don't understand where she believes the problem lies. Although I am interested in whether technology is hurting my students, her statements seem uninformed and politically biased.

After reading countless articles I began to wonder about a different question, "What

effect will limiting calculator usage have on students' problem solving skills?" Adding problem solving to my search criteria, I encountered an article by Wheatley (1980). Wheatley conducted a pilot study with twenty-five students in a fifth grade class in order to see what effect calculators would have on the students' problem solving abilities. Based on her findings, she believes that calculators can facilitate mathematics performance with little risk of loss of computational proficiency. This surprised me. Wheatley wanted to know if a student was permitted to use a calculator on a regular basis, then would the student be more focused on strategy needed to solve a problem. Based on this study Wheatley concluded that students who are permitted to use calculators spend approximately the same amount of time on task as those who are not. This was in agreement with the article by Bridgeman, Harvey, and Braswell. The calculator group had fewer computational errors and spent more time on the process of problem solving as opposed to computation. Wheatley's findings appear to support the beliefs of NCTM that technology promotes problem solving (Wheatley, 1980, p. 323-334). However, I still wonder about computational proficiency. Huntley, Rasmussen, Villarubi, Sangtong, and Fey (2000) conducted a comparative study of the effects of the Core-Plus Mathematics Project curriculum and a more conventional curriculum with regards to growth of student understanding, skill, and problem-solving ability in algebra. In their article, they claim that although the use of a calculator offers a student a variety of powerful new learning and problem solving strategies, it diminishes the need for that student to acquire a high degree of skill in symbol manipulation (Huntley, Rasmussen, Villarubi, Sangtong, & Fey, 2000, p. 331). Is this what I want for my students?

Forster and Taylor (2000) studied an eleventh grade Geometry and Trigonometry class of eighteen students in a private college for girls in Western Australia. In this classroom, graphing calculators were used on a regular basis, and the learning conditions were considered to be

exemplary. Based on their findings, Forster and Taylor consider technology to be a tool or a partner for the student. They see the students not only using the tool to improve problem solving, but also taking what they have learned from the tool and applying it elsewhere (Forster & Taylor, 2000, p. 38).

Similarly, I found several articles that supported the use of calculators, specifically graphing calculators, as tools that deepen a student's understanding of abstract or merely difficult mathematical concepts. One such concept is the idea of a variable in Algebra. Graham and Thomas (2000) conducted a pilot study in five United Kingdom schools using the TI-80 graphing calculator. This study focused on variables, one of the more difficult topics in Algebra. They implied that the students who used graphing calculators could gain a better understanding of the use of letters as variables, without an adverse effect on their basic ability to manipulate the symbols to solve an equation or inequality (Graham & Thomas, 2000, p. 271). Graham and Thomas believe the students involved in this study all saw an increase in understanding but stated that the students with the lowest ability appeared to show the most improvement (Graham & Thomas, 2000, p. 279). The authors, however, did note that one teacher involved with their study stated that her students were very reluctant to give up the calculators. Her students had become dependent on the technology and feared failure without it (Graham & Thomas, 2000, p. 277). This sounds like my students, many of whom want to push the buttons on the calculator to do the simplest of tasks such as dividing by negative one.

This led me to my final question, "What effect will limiting calculator usage have on students' abilities to justify the reasonableness of an answer?" I have determined that a student with a calculator in hand often loses his or her common sense. One of my freshmen was convinced that her solution to a distance problem was correct. In her defense, the problem was a

little tricky. The students were given a problem that would generate the stopping distance a car would need based on the speed it was traveling. The tricky part of this problem was that the students were asked, after several reasonable situations, what the stopping distance of a parked car would be. This student plugged some numbers into her calculator and came up with a negative distance. When I asked her if this made any sense, she insisted it was right because that was the number the calculator had given her. I asked her the speed of a parked car, and she knew that it was zero, but it took a lot of talking on my part before she would admit that her answer didn't make any sense. Do students really think that calculators are intelligent? Don't they understand that a calculator merely performs the actions asked of it?

Doerr and Zangor (2000) conducted a classroom-based study in order to better understand the meaning of a tool such as the graphing calculator as it was constructed by both teacher and student. They also hope to understand how the student used the tool to construct mathematical meaning out of particular tasks. Doerr and Zangor sing the praises of the graphing calculator as a computational tool, transformational tool, data collection and analysis tool, visualizing tool, and a checking tool for students (Doerr & Zangor, 2000, p. 161). These authors did, however, note the limitations of this tool. The first limitation is the students' idea that the calculator is the magic black box. They implied that occasionally the students didn't have a meaningful strategy for using the calculator, but rather pushed buttons rather than attending to the meaning of the problem presented to them. The second limitation was the effect that calculators had on group work. Students tended to use their calculators as private devices which often led to the breakdown of group interactions (Doerr & Zangor, 2000, p. 158). This seems reasonable because students could be at different stages of the problem, based on their ability. Students seldom second guess what the calculator says and feel free to continue without

verification from the group.

Although these studies have given me a great deal to consider, not one study evaluated calculator use in the middle grades. Middle school students are unique in the manner in which they approach problems. They have the knowledge foundation from elementary school, but they are not always certain how, when, or where to apply it. Given a powerful tool like a scientific calculator, will they use it wisely or merely mindlessly push buttons? Middle school students are the heart of my study, and I feel they are what sets this paper apart from the others based on this topic.

Purpose Statement

The purpose of my problem of practice research is to attempt to uncover the effect that technology has on student learning, specifically the effect of permitting calculators in grades seven, eight and nine. A lot of the research that I have read for this project sings the praises of technology in the classroom, and prior to last year I would have agreed without hesitation. I am now concerned about the effect that unlimited calculator use has on students. While I would never want to teach in a technology-free classroom, I want to try to determine if and where boundaries need to be set. My greatest concern is for my middle school students, so I am going to limit my seventh and eighth grade students' calculator usage. I plan to give a pre- and post-test and several habits of mind problems to determine the effect the limitation has on computational skills, problem solving, and reasoning skills. I feel this study is necessary in a world that is becoming more technologically advanced. In wanting to give our students every advantage, are we undermining their education, or is there merely a need to cling to the familiar?

The questions I considered were:

- What effect will limiting calculator usage have on student achievement?

- What effect will limiting calculator usage have on students' problem solving skills?
- What effect will limiting calculator usage have on students' abilities to justify the reasonableness of an answer?

Method

This study was conducted in my eight grade mathematics classroom during the spring semester, 2007. Because my initial concern was the scores the students received on the computation section of their achievement tests, this remained a major focus of this study. I decided to collect achievement test scores from the same set of students over a three-year period. I wanted to see the change in their computational scores from sixth grade where no calculators were used, seventh grade which allowed unlimited calculator use, and eighth grade which allowed limited calculator use. The school's guidance counselor gave me a copy of all three sets of scores on May 1, 2007. I then put the data into a spreadsheet so that I could visualize the change. I also calculated the mean and standard deviation of the differences from sixth to seventh grade, seventh to eighth grade, and sixth to eighth grade.

Similarly, every year I give a semester test in December and a final in May for every class that I teach. Because I wanted to compare this year's Math 8 tests to last year's tests, I decided to give the same form I had given last year. On the semester test students were permitted to use calculators. On the final test students were not permitted to use calculators. I keep copies of these tests, so this data was also easy to collect. I then put the data into a spreadsheet so that I could see the change and calculated the mean and standard deviation of the differences last year to this year.

To see how or if calculator usage affected the student's problem solving skills, I had the students do habits of mind problems. These problems were given every other week, starting the

week of March 19th, 2007. They were complicated problems that involved more than simple computation. I permitted calculator use on some of the problems and forbid them on others. While grading these problems I looked for a logical thought process, sound mathematics, a reasonable explanation, and the correct answer. I used a rubric to grade these problems (see Appendix A). From this data, I chose four of the best samples to compare. Two samples allowed the use of calculators, and two did not. I wanted to see if there was any difference in the problem solving process, and if the answers to the problems were reasonable and well justified.

Finally, I asked my students to give daily homework presentations starting the week of March 19th, 2007. I would choose three to five homework problems each day, and students took turns presenting these problems on the board to their classmates. Students were expected to show all of their work and were not permitted to use a calculator. These presentations were also graded with a rubric (see Appendix B). From this data, I looked at each individual student to see if their problem solving skills were improving or declining and if their answers made sense and were justifiable.

Findings

What effect will limiting calculator usage have on student achievement?

As I have mentioned in previous sections, one of the main reasons I chose to do this topic for my action research project was because I noticed the computation section of my students' achievement test scores was low. In order to determine if there was any improvement, I decided to compare the computation scores of my current eighth grade students to scores for these same students when they were in both sixth and seventh grade. The data I gathered from the achievement tests can be seen in Appendix C.

Based on the data that I was able to compile and compare, I believe that my students did

show a slight improvement in the computation section of the achievement test this year. I looked at the differences for each student from sixth grade to seventh grade, from seventh grade to eighth grade, and from sixth grade to seventh grade. The mean of the differences from sixth to seventh grade was -3.43 with a standard deviation of 22.46. This means many of the students saw a drop in their computation scores in seventh grade, eight of fourteen to be exact. This means unlimited calculator usage had a negative, though minimal, effect on their scores. The mean of the differences from seventh to eighth grade was 4.57 with a standard deviation of 14.98. This means there was an increase, though small, in the students' computation scores when I chose to limit calculators in the classroom. The mean of the differences from sixth to eighth was 1.14 with a standard deviation of 27.01.

I was surprised to discover that six of my fourteen students achieved their highest score on their eighth grade test. I assumed that the sixth grade score would be the highest for everyone, because most of the mathematics in elementary has to do with computation. Ten of my fourteen students scored higher this year than they did in their seventh grade year, so approximately seventy-one percent of my students seemed to benefit from limiting calculator use.

Every year I give a semester test and final for every class I teach. This year, as I had mentioned in the previous section, I chose to give the same test so that I could compare this year's scores to last year's scores. The means of the semester tests were quite close. The mean was 90 for last year and 91 for this year. However, the standard deviation for last year was larger; the standard deviation for last year was 8.49, and it was 4.83 this year. I believe the differences in the standard deviation could be due to last year's class size and make up. There were 12 students last year and 16 students this year. The means of the final exams were also fairly close; the mean was 88.4 last year and 91.7 this year. However, there was a slight increase

with this year's class. The standard deviations of 10 last year and 6.3 this year may have had a greater difference, once again based on class size and make up.

Wanting to know more, I decided to generate a box and whisker plot (see Appendix D). The median for the semester test was higher last year, but the values had a greater range. The first quartile this year was higher, but the third quartile was higher last year. Overall, based on the plots, I believe the semester tests were fairly even. Looking at the plots for the final exam, however, there does seem to be an increase in the scores this year. This year's median is slightly lower than last year's, but both the first and third quartiles are higher, and the range is smaller. This data supports my belief that my students did show a slight improvement when calculators were limited.

The problem I have with answering this question solely on the basis of two tests is my definition of achievement. Some people only choose to look at test scores when they make the decision as to whether or a not a student is achieving. I, on the other hand, prefer to look at the students as a whole. Some of these students have shown such great progress, yet this can be difficult to see on any standardized test. One of the dynamics of this class is that as sixth graders a handful of these students were placed back in the fifth grade text because their teacher didn't believe that they were capable of sixth grade math. I feel that this is one of the most detrimental things that can be done to a child, especially these kids. When I started seventh grade with them there was such a division in ability based primarily on a lack of confidence. When I gave these students permission to use calculators, I felt like I evened the playing field. These students, who were convinced that they would never be successful in math, began to achieve by leaps and bounds. One student, who claimed that he had hated math during his seventh grade year, actually asked at the end of this year if he could try to take algebra, because "I think I finally understand

how to use the letters." This student had failed sixth grade math. This to me is achievement, and this happened with the aid of technology.

What effect will limiting calculator usage have on students' problem solving skills?

I believe, based on evidence gathered from Habits of Mind problems and daily homework presentations, that my student are more successful problem solvers when technology is available. My focal point for these problems was problem solving and reasoning. First, I compared solution to habits of mind problems when calculators were and were not permitted. While grading these problems I looked for a logical thought process, sound mathematics, a reasonable explanation, and the correct answer. I used a rubric to grade these problems (see Appendix A).

I discovered that without a calculator my students seemed to focus on computation. One example of this occurred when I had my students do the MATH problem. The math problem consists of sixteen letters arranged in a diamond shape (see Appendix E). The students are asked to figure out how many ways there are to get from the top M to the bottom H, given that they can only go diagonally down. One of my students started multiplying the number of letters in each row (1 * 2 * 3 * 4 * 3 * 2 *1 = 144), and then proceeded to add the numbers in each row (1 + 2 + 3 + 4 + 3 + 2 + 1 = 16). She brought her paper up to me, and said, "Here! I know it has to be one of these since we can't use our calculators." I asked her to think about the problem, to which she replied, "I knew I multiplied wrong. I need a calculator!" I told her that her multiplication was right, but her approach to the problem was incorrect. She took her paper and sat back down, but she didn't change her answer; this was one of my better students.

On the contrary when I permitted calculators, the focus seemed to shift to problem solving. One example of this occurred when my students worked on the chessboard problem. We had just completed a section in our text that dealt with scientific notation and large numbers, so I

decided this problem would be appropriate. This problem tells the students about a king who was so excited about learning to play the game of chess that he offered his teacher anything. The teacher asked for rice; he asked for one grain on the first square, two on the second, four on the third, doubling on each new square for every square on the chessboard. Because of their youth, I assumed most would continue doubling and then add the numbers together. I was excited to have a student write," Because the numbers got too large, I decided to try a smaller board to try and find a pattern." He continued, "I noticed, by using a two by two and a three by three, that when you add up all the rice it is the same as multiplying the last square by two and then subtracting one." He didn't get the final answer but his thought process was wonderful. Another student knew that the last square would have 2^{63} grains of rice but didn't know what to do because her calculator had given her an overflow error.

I also asked my students to give daily homework presentations. I would choose three to five homework problems each day, and students took turns presenting these problems on the board to their classmates. Every student had to present at least once a week. Students were expected to show all of their work and were not permitted to use a calculator in class. These presentations were also graded with a rubric (see Appendix B). After each student had presented, fellow classmates were encouraged to ask questions. This really seemed to boost my students' problem solving skills. They had to think quickly and usually didn't need a calculator to give their opinion or solution. In this respect, not having calculator didn't seem to affect their skills. I believe this was because they were already familiar enough with the problem, and their confidence didn't waiver when peers asked them questions.

What effect will limiting calculator usage have on students' abilities to justify the reasonableness of an answer?

I believe that when my students didn't have a calculator, provided that no basic math errors were made, they were actually a little bit better prepared to answer the question "Is that reasonable?" Again I will turn to the data gathered from the Habits of Mind problems and daily homework presentations. One of the things that I was a stickler about was showing every bit of the work needed to obtain any answer. This was true for both the Habits of Mind problems and the homework presentations, so even when calculators were permitted the students had to show every step. With the Habits of Mind, I also tried to encourage them to write in complete logical sentences, mathematical or otherwise. I believe that this helped the students think through their answer and their thought process. The Habits of Mind problems were done in class, and I decided based on the problem whether or not calculators would be used. I believe overall that students were better able to justify their answer, because they had to show all of their work regardless if technology was present.

For the most part, students did very well with the daily homework presentation problems, but I question my data based on the fact that the students did most of the required problems at home where the students did not know if they were supposed to use a calculator or not. Because the students knew that they had to show all of their work on the board, they did seem to work through the problems by hand, but I am fairly certain that most checked their answers with a calculator, perhaps motivated by fear of ridicule by their peers. I believe, once again, that the step-by-step break down of the problem lent itself to improved reasoning.

Conclusions

What effect will limiting calculator usage have on student achievement?

Based on my findings, I would have to say that the answer to this question depends largely on how one chooses to define achievement. I did see improvement in my students'

achievement test computation scores, so clearly there was good reason to question calculator use. The study by Bridgeman, Harvey, and Braswell seemed to show that the use of calculators on a standardized test resulted in a modest increase in test scores (Bridgeman, Harvey & Braswell, 1995, p. 323-340). My data appeared to show the opposite is true for the computation section of the test which does not permit calculator use at all. I also saw a minimal improvement in my final exam that I gave this year. I am not certain, however, if either of these compare to the result I was getting with some of my students when calculators were permitted.

What effect will limiting calculator usage have on students' problem solving skills?

I would have to say based on my findings that without a calculator there was some decline in my student's problem solving ability. I tried to use Habits of Mind problems that forced the student to think, but when I didn't let them use calculators it seemed like some of them no longer could think. It wasn't that they used the calculators that much; it was more that they needed to know that the calculator was there if they needed it. This probably occurred in part because they were permitted to use calculators whenever they felt like it last year in my classroom. I share the fear of one of the teachers involved with the study conducted by Graham and Thomas; my students have become dependent on the technology and fear failure without it (Graham & Thomas, 2000, p. 277).

What effect will limiting calculator usage have on students' abilities to justify the reasonableness of an answer?

My students' reasoning skills did improve, but I am not certain of why this occurred. I believe that students were getting better at checking their work because they had to give their oral presentations to the class. They got used to me asking them if something made sense, and they knew that they needed to be sure that it did. I have no idea if calculators were used at home,

but I do know that having to explain and teach something to someone else makes you more thoughtful of your words and work. I believe that prior to this study my students sometimes thought of the calculator as the magic black box. Similar to the study by Doerr and Zangor, sometimes my students didn't have a meaningful strategy for using the calculator but pushed buttons rather than attending to the meaning of the problem presented to them (Doerr & Zangor, 2000, p. 158). When forced to show all of their steps and write their thoughts down, my students have become more thoughtful which in turn has improved their reasoning skills.

Implications

Although not all of my results were as clear as I wanted them to be, I do think that teaching a student to use a tool and allowing a student to become dependent on a tool are two very different results. I will always permit my students to use calculators if the task deems them necessary, but I will now set restrictions. I don't think it hurts to remind the students how to multiply or divide by hand, especially since I don't think the computation section of our achievement tests will be changed any time soon. Most adults use a calculator on a regular basis, but struggle to see the calculator's use in the classroom. They want their students to be taught in the manner that they were taught. After all, they turned out all right. I firmly believe that math education needs to focus less on computation and more on problem solving.

I plan to keep the Habits of Mind problems as well as the daily presentations a permanent fixture in my classes. I believe that both of these practices, which were borrowed from the Math in the Middle Project, allow my students to grow academically and are very worthy of class time. I also have insisted on more work being shown and have lessened the number of problems I require my students to do with the emphasis on quality over quantity.

My recommendations to teachers who face a similar situation is to not be afraid to let

your students gain what they can from technology, but also don’t allow them to become dependent. Require your students to show all of their work, and challenge them to support their answers. Encourage your students to think, and teach them how to properly use the tools provided by today’s technology.

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Appendix A

Habits of Mind Rubric

Logical thought process: 1 2 3 4 5 6 7 8 9 10

- Did the student's work appear to follow a logical sequence? Yes No
- If not, is there a reason for the deviation?

_____
_____
_____

Sound mathematics 1 2 3 4 5 6 7 8 9 10

- Is the student's work mathematically sound? Yes No
- If not, explain:

_____
_____
_____

Reasonable explanation 1 2 3 4 5 6 7 8 9 10

- Does the student's explanation make sense? Yes No
- If not, explain:

_____
_____
_____

Correct answer 1 2 3 4 5 6 7 8 9 10

- Is the answer correct? Yes No
- If not, where/why did the error occur?

_____
_____
_____

Calculator: 1 2 3 4 5 6 7 8 9 10

- Did the student use a calculator? Yes No
- If yes, how did it affect their thought process?

_____
_____
_____

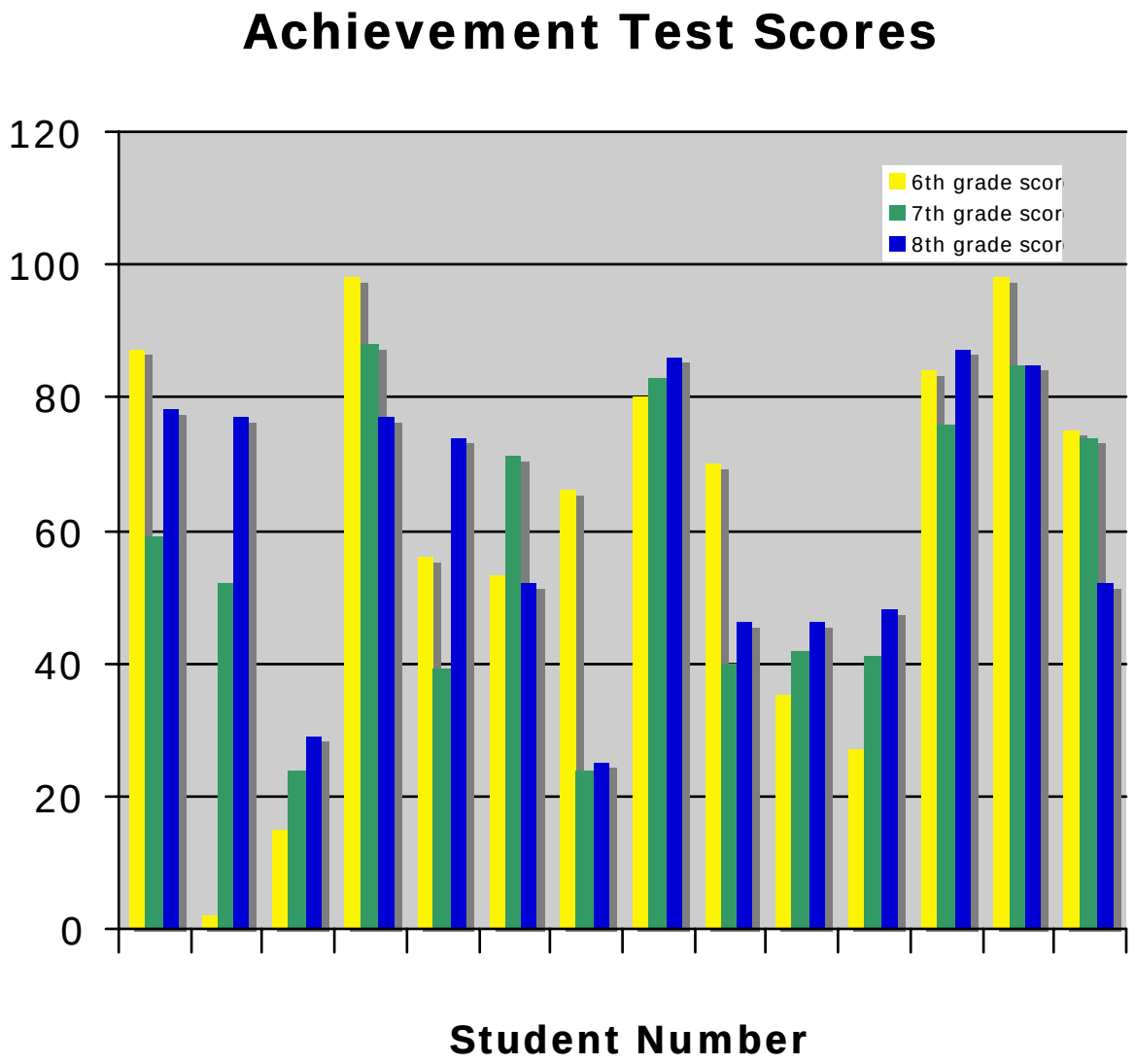
Comments:

Appendix B

Student Presentation Scoring Guide

	Rating (1-5)	Comments:
Logical thought process		
Sound mathematics		
Reasonable explanation		
Correct answer		
Total (4-20)		Calculator: Yes N

Appendix C



6 of 14 achieved their highest score during their 8th grade year.

10 of 14 did better their 8th grade year than they did their 7th grade year.

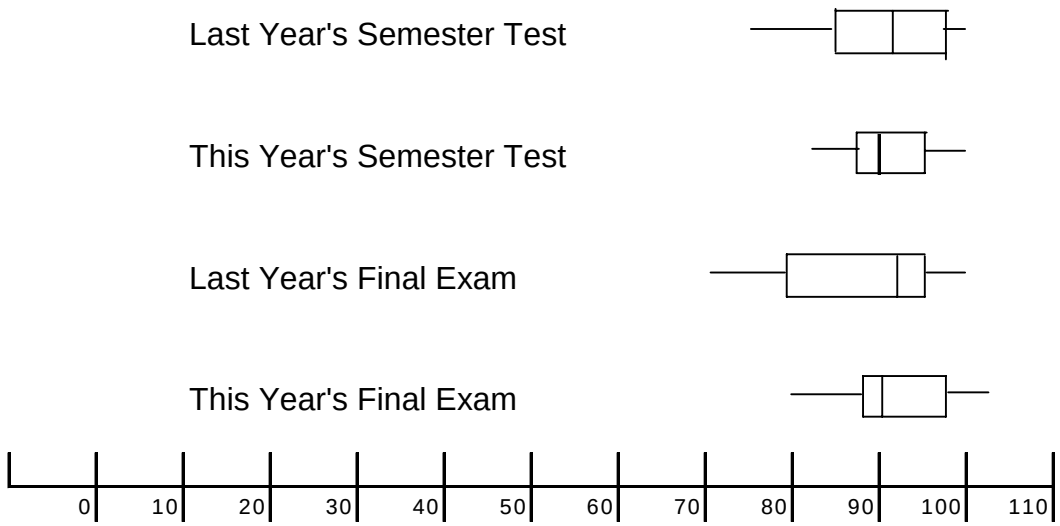
The mean of the differences from 6th grade to 7th grade is -3.43 with a standard deviation of 22.46.

The mean of the differences from 7th grade to 8th grade is 4.57 with a standard deviation of 14.98.

The mean of the differences from 6th grade to 8th grade is 1.14 with a standard deviation of 27.01.

Appendix D

Semester Test and Final Comparison



	Semester Test-2005	Semester Test-2006
Mean	90	91
Variance	72.18181818	23.36666667
Standard Deviation	8.495988358	4.833908012
Median	93	90
1st Quartile	84.5	87.875
3rd Quartile	96.5	95
Maximum	100	100
Minimum	76	83
Range	24	13
Sample Size	12	16

	Final Exam-2005	Final Exam-2006
Mean	88.41666667	91.6875
Variance	99.90151515	40.09583333
Standard Deviation	9.995074545	6.332127078
Median	92.5	91
1st Quartile	79.25	87.5
3rd Quartile	96.25	97
Maximum	100	103
Minimum	71	80
Range	29	23
Sample Size	12	16

Appendix E

M

M A

M A T

M A T H

A T H

T H

H