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Student arithmetic error rate with and without calculators

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STUDENT ARITHMETIC
ERROR RATE
WITH AND WITHOUT
CALCULATORS

MASTER'S PROJECT

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CHAPTER I

INTRODUCTION

Purpose of the Study

Today, the use of calculators and other technology is an integral part of our existence. Surveys show of 100 occupations, which involve some form of mathematics, 98 percent of respondents use calculators on a daily basis. Students are being allowed to use calculators in the class, on homework, on examinations, and even on standardized tests (Usnick, Lamphere, & Bright, 1995).

In 1989, the National Council of Teachers of Mathematics (NCTM) set forth new standards for teachers to implement in the classroom. The Curriculum and Evaluation Standards for School Mathematics addresses teaching mathematics in Kindergarten through 12th grade. The NCTM recommends all students should have access to calculators and the calculator should be used as a tool for accomplishing the task at hand (NCTM, 1989). The NCTM also recommends the calculator not replace knowing the algorithm for finding the answer (NCTM, 1996). Students still need an understanding and knowledge of basic arithmetic calculations. This means teachers must integrate the concepts along with the appropriate use of the calculator. Calculators are currently being used for a multitude of situations in the classroom.

The use of calculators allows students to concentrate on more than just computations. Students can look at patterns that exist in problems and analyze information to enable them to resolve problem situations. Using calculators in the classroom also allows teachers the opportunity to display the proper and appropriate use of the calculator (Clayton, Dorough, Scott, & Wilson, 1990). The use of calculators in the classroom does allow students not to get overly concerned with their ability to complete computations. Yet, students are prone to making errors while accomplishing calculations with a calculator as well as making errors using pencil-and-paper.

To date, most studies are concerned with either attitudes toward calculators or students achievement when using a calculator. Yet what difference does the calculator actually make on student arithmetic error rate? It is the writer's opinion that students make fewer arithmetic errors when using a calculator than when doing the calculations with pencil-and-paper.

Problem Statement

The purpose of this project is to determine if middle school mathematics student's arithmetic errors are greater without the use of a calculator or with the use of calculators.

Hypothesis

There was no significant difference in the student arithmetic error rate between the pre-test and post-test mean scores when not using a calculator. There was no significant difference in the student arithmetic error rate between the pre-test and post-test mean scores when using a calculator.

Assumptions

In order to carry out this study, the writer made the following assumptions. First, the tests measured what they are designed to measure. Secondly, the writer assumed the students would take the test with honesty and performed to the best of their ability.

Limitations

The writer found several limitations effecting this project. In using the T_1 X_a T_2 and T_1 X_b T_2, the control group was Group 2 who did not use the calculator. Group 1 was the group which used the calculator. One limitation the writer found was that Group 1 was given the test immediately after their recess. In this class, students were still trying to settle back into class when they took the tests. Group 2, the control group, might have been distracted due to the closeness of the end of the day. In the afternoon, the building was warmer due to the lack of air conditioning. Students in each of the groups may have had trouble concentrating due to higher temperatures in the classroom. The writer was limited to the ability of the students at hand. There was no attempt to randomize the selection of students in each of the classes. The writer was limited to the forty-one students in the study. The remaining limitations dealt with factors of the internal and external validity of the design (Isaac & Michael, 1995).

There were factors that influenced the internal validity of this study. Students had access to calculators outside of the classroom without the writer's knowledge. Thus there was the effect of history. This project was conducted over a two-and-a-half month period of time so maturation influenced the outcome. The pre-test alerted the students of what was being done for each part. Statistical regression had an impact on the results of this study. Since classrooms have students come and go, there was the possibility of experimental mortality affecting the study. And last, was differential selection of subjects as one mathematics class might have had a higher ability than the other.

The factors affecting external validity included confounding effects of pre-testing and interaction of selection and treatment.

Definition of Terms

Algorithm was a multi-step process to answer to a math problem.

Arithmetic error was an incorrect answer when given a problem that involves a calculation. Calculations involve the use of operations which include addition, subtraction, multiplication, and division.

Basic math facts were the one digit math problems which involve addition, subtraction, multiplication and division.

Calculator was any electronic computing device the student chooses to use.

Group 1 was the writer's fifth period mathematics class.

Group 2 was the writer's sixth period mathematics class.

Mental math was accomplishing an assignment not using pencil-and-paper or calculator.

Middle school math students were the seventh grade students used in this study.

Pencil-and-Paper method was accomplishing an assignment using only a pencil and a piece of paper to calculate an answer.

CHAPTER II

REVIEW OF RELATED LITERATURE

Calculating the solution to a problem is a skill which people begin to learn very early in life. In first grade, people formally begin to learn the basic math facts. These facts are the basis for later concepts presented in math, such as algebra, geometry, and on up to calculus. Yet being human, people make mistakes when calculating answers to math problems. There are those who believe that using a calculator alleviates the occurrence of errors and wrong answers. Student arithmetic error rate with and without a calculator is the focus of this study. In reviewing the literature, three areas came to light concerning calculations. The first area the writer will discuss is the types of calculations students encounter in their education. The second area the writer will discuss is the use of calculators in math education. The last area the writer will discuss is the type of errors which students have been found to make when calculating the answer to a problem.

The calculations which students encounter during their education involve addition, subtraction, multiplication and division. These are calculations which they will encounter on a daily basis throughout their lives. In the early stages of the educations, students use objects to understand addition and subtraction. They begin to use pencil-and-paper when the problems become more involved and they are more capable of writing. During the primary years, first through third grade, students learn addition and subtraction of whole numbers. In the fourth grade, students encounter multiplication and division of whole numbers. These are facts most student's learn by memorization. The 1978 NCTM yearbook, <u>Developing Computational Skills</u>, discusses the "desirable level of computational skill" for students. It states there are "390 addition, subtraction, multiplication, and division combinations" which students should be able to recall without any trouble (Hamrick & McKillip, 1978). These skills are part of the basic facts students learn early on in their math education. Students should also know the "standard computational algorithm" for the four basic operations (Hamrick & McKillip, 1978). The author includes the "areas of estimating, rounding, mental computation, and judging an answer's reasonableness" as items that students should learn as part of the desirable level of computational skill. Hamrick and McKillip state that there are at least four reasons for "advocating the attainment of" a desirable level of computational skill. They are as follows:

"First, it facilitates the learning of subsequent related topics. Second, computational skill helps pupils to understand both the meaning and the significance of arithmetic operations and to apply these operations appropriately. Third, it facilitates an exploration of various topics, generalizations from data, and the recognition of generalizations. Fourth, some aspects of computational skill continue to have considerable social utility."

Later in a student's education, they begin to learn more complex ideas. The 1982 NCTM yearbook, <u>Mathematics for the</u>

Middle Grades (5 - 9), discusses the topics which students should encounter during their pre-adult years. Students are introduced to fractions, decimals, and the concept of rational numbers. Students learn to calculate the result to addition, subtraction, multiplication, and division for these type of numbers. In their high school years most students begin learning concepts in algebra, geometry, trigonometry, and sometimes get as far as calculus. The basic math facts they learn in the early years are essential for them to accomplish the challenges they face in other math areas. Yet, while the basic facts are important for students to know and be able to calculate with pencil-and-paper, technology is an ever present tool for students to use when calculating large problems. In the next section, the writer will discuss the calculator in the classroom.

In 1975, the National Advisory Committee on Mathematical Education began to encourage teachers to use calculators in the classroom. In 1986, the NCTM "recommended that mathematics programs [should] take full advantage of calculators" (Harvey & Bright, 1991). There are many reasons for the use of calculators in the classroom. Some say that calculators "help teachers develop concepts about numbers and counting, the four arithmetic operations, decimals, and estimation" (Suydam, 1983) and mathematical reasoning (Battista & Lambdin, 1994). Calculators are set-up so that by using either the addition sign or the equal sign a student can investigate increasing a number by the increment (Beardslee, 1978). Students can reinforce their knowledge of reading numbers correctly by listening to a teacher read a set of numbers to them and typing the numbers into the calculator. After the teacher is done with the list of numbers, the student can push the equal sign to see what the result is. If the students typed the numbers into the calculator correctly then their result should match that of the teacher (Beardslee, 1978). Calculators allow students to go beyond the "tedious computations" and concentrate on problem solving (Clayton, Dorough, Scott, & Wilson, 1990). When students use the calculator to solve problems, they are essentially equal in computational ability and can concentrate on finding the important information to solve the problem rather than the numbers being calculated (Beardslee, 1978). Calculators can also be used to find patterns. In the 1978 NCTM yearbook, Beardslee states that the "calculator provides the opportunity for investigating patterns that would be tedious and time-comsuming with only pencil-and-paper". Some of the examples given are $1^2 = 1$, $11^2 = 121$, $111^2 = ?$ and $1111^2 = ?$. This gives students the opportunity to discover the pattern that exist for this problem (Beardslee, 1978). In order for students to effectively use calculators, teachers must instruct students on the appropriate and proper use of calculators (Higgins, 1990; Battista & Lambdin, 1994). Calculators should be used to assist students in calculations. Teachers must show students when a calculator is necessary and when they should accomplish the problem using pencil-and-paper or mental math (Higgins, 1990; Battista & Lambdin, 1994). Students should not instinctively reach for a calculator when presented with a problem. The writer has discussed reasons for calculators in the classroom. Next, the writer will discuss the categories of arithmetic errors.

The research found on arithmetic errors listed four categories of arithmetic errors. They are basic fact error, wrong operation error, random error and procedural error.

The first arithmetic error is the basic facts error and has two error sub-types. The first error sub-type is when a student simply does not know their basic facts (Brumfield & Moore, 1985; Inskeep, 1978). The second error sub-type "occurs when the child does not understand the concept of the operation" (Inskeep, 1978). For example, a student might have memorized his/her multiplication facts and is able to tell you that 6 times 4 equals 24. Yet this student may not know that multiplication is the same as repeated addition. Inskeep (1978) says this error sub-type is not "easy to ascertain" in a student's pencil-and-paper work and an in-depth analysis is required to diagnose this error sub-type.

The second arithmetic error is the wrong operation error. A student with a wrong operation error has accomplished a problem using an operation other than the one in the problem. For example if the problem given is 89 + 12 =, a wrong operation error occurs when a student accomplishes the problem using an operation other than addition (Ashlock, 1972).

The third arithmetic error is the random error. This type of arithmetic error occurs when "students are inconsistent in their error pattern". This means students find "different incorrect answers" for the same problem at different times (Brumfield & Moore, 1985; Inskeep, 1978).

The fourth arithmetic error is the procedural error. This is an error that occurs when "students know the basic facts but do not understand the algorithm that should be used and may devise their own algorithms, thereby having a clearly identifiable pattern for arriving at incorrect answers" (Brumfield & Moore, 1985; Coker, 1991; Inskeep, 1978; Tatsuoka, 1984).

The writer also found in the research of arithmetic errors a fifth error type which is a "failure to respond" category. This happens when a student simply does not attempt to accomplish the problem given. This may or may not mean that the student does not know how to work the problem (Inskeep, 1978). It could also mean that the student did not have enough time to accomplish the problem. These types of arithmetic errors can be diagnosed by the teacher. Remediation can then take place for each student. There is a plethora of information to help teachers in diagnosing and re-mediating the types of errors discussed above. Though the information found above deals mostly with pencil-and paper problems, the writer feels that these error types discussed in this section can be applied to the use of calculators.

In conclusion, we all need to know how to accurately accomplish arithmetic problems to exist in our society today. Whether it is by pencil-and-paper, mental math or calculator, we should all have an understanding of the correct use of each method. In our society, the move towards technology is a popular one. We have calculators and computers all around us and they are taking over areas we deal with daily. Our students need to be introduced to the new technology and allowed to use technology. Teachers must find a balance between having students find the result by hand and mind versus by calculator.

CHAPTER III

PROCEDURE

Subjects

The subjects were forty-one seventh grade students of mixed abilities ranging from below seventh to ninth grade mathematics levels.

Setting

School. The writer's building contained students in grades kindergarten through eighth grade.

Community. The school system was in Southwest Ohio. It occupies a single building in a residential area.

Data Collection

Construction of the Data Collecting Instrument. The writer used a teacher generated pre-test and post-test to determine the student's average mean test score to the measure students arithmetic error rate when not using a calculator. The writer used a teacher generated pre-test and post-test to determine the student's average mean test score to the measure students arithmetic error when using a calculator.

Administration of the Data Collecting Instrument. The pre-test and post-test were given to the students to be accomplished individually. The writer expected to have a 100 percent return rate for each test given.

Design

The writer used a classical T_1 X_a T_2 and T_1 X_b T_2 design in which she manipulated only one independent variable (Isaac & Michael, 1995). The T_1 represented pre-testing for the student's arithmetic error rate when not using a calculator. The X referred to the independent variable of using the calculator versus not using the calculator to calculate answers to math problems. The T_2 represented post-testing for the student's arithmetic error rate where Group 1 did use a calculator and Groups 2 did not use a calculator. There was no deliberate attempt to randomize students in each group. Yet when the students were assigned to their math class, student's names were put into alphabetic order and the list was split in half. Therefore the groups were randomized. The pre-test and post-test consisted of fifteen problems which students completed in a fifteen to twenty minute time frame during a regular class period. The test contained addition, subtraction, multiplication, and division. These are concepts which students reviewed during the first six weeks of the school year. A sample of each test is in appendix A. Each test contains the same problems but in different order. The forty-one students were broken up into two groups. Group 1 consisted of 22 students and Group 2 consisted of 19 students.

Treatment

For this experimental study, the writer's independent variable was using the calculator verses not using the calculator to calculate answers to math problems. Students in this study were not allowed to use calculators at the beginning of the school year. In the middle of the second quarter, the Pre-Test (appendix A-1) was administered. The next day students were allowed to begin using calculators. Students were encouraged to use calculators for the next five weeks on all assignments and at home. Students received classwork and homework from the textbook. They were also given quizzes and tests allowing them to use calculators. Topics covered during the five weeks included angles and line relationships, simple algebra equations, and the beginning of number theory. Then, student's took the Post-Test (see Appendix A-2).

CHAPTER IV

RESULTS

Presentation of the Results

The writer computed the mean as the measure of central tendency and the standard deviation as the measure of variance for the Pre-Test and Post-Test scores from the tests. The results are below.

Results of Math Calculations with and without Using Calculators

TEST	N	$\overline{X}$	S
Pre-Test w/out calculator			
Group 1	22	83.91	11.26
Group 2	19	74.79	14.07
Post-Test			
Group 1 w/ calculator	22	91.18	10.09
Group 2 w/out calculator	19	73.79	13.83

Discussion of the Results

The writer will discuss the results of calculating the t-test for the null hypothesis, the mean score average of the Pre-Test and Post-Test, the percent of student arithmetic error, and the items missed most often by students on the tests. The writer will begin with the results from the t-test.

The samples were treated as dependent samples and a t-test for means of dependent samples was run. It was assumed that the scores came from a normally distributed population. The formula, t=(d-u)/(s/square root of n) was used to calculate the t value. The d is the mean of the differences, u is 0 since it is the theoretical difference between the means, s is the standard deviation of the differences, and n is the sample size (Triola, 1992). The alpha was set at .05 when looking at the critical value table.

For Group 1, the observed value was found to be 2.371. The critical value was a plus or minus 2.080. In light of the results of this study, the writer finds that there is sufficient evidence to warrant rejection of the claim that there is no significant difference in the student arithmetic error rate between pre-test and post-test mean scores when using a calculator. It was found that students make fewer arithmetic errors when they have a calculator to use.

For Group 2, the observed value was found to be -0.34. The critical value was a plus or minus 2.101. In light of the results of this study, the writer finds there is not sufficient evidence to warrant rejection of the claim that there is no significant difference in the student arithmetic error rate between pre-test and post-test mean scores when not using a calculator. This means students make more mistakes when not allowed to use the calculator. Students do not find the solution to a problem correctly when asked to find it with pencil-and-paper. Now the writer will look at the mean scores for each group.

As shown on the chart on the first page, the mean score for Group 1 was 83.91 on the Pre-Test, and a 91.18 on Post-Test. The mean for the percent of problems missed by Group 1 are as follows:

Test Name	Percent Missed	Number of Problems Missed Per Student
Pre-Test	16.09	2 to 3
Post-Test	approx. 10	1 to 2

In Group 2, the students used the calculator for six weeks and then took the Post-Test without the calculator. The mean score for Group 2 was 74.79 on the Pre-Test, and a 73.79 on Post-Test. The mean score averages for Group 2 remained fairly consistent throughout the testing period. As can be seen, the mean did decrease 1 point after using the calculators and then taking the Post-Test without the calculators. The percent of missed problems dropped by one point also. The mean for the percent of problems missed by Group 2 are as follows:

Test Name	Percent Missed	Number of Problems Missed Per Student
Pre-Test	25.21	3 to 4
Post-Test	26.21	about 4

From the Pre-Test to Post-Test, there is no improvement in the number of errors students make. Now let us look at the problems the students missed most often for each test.

As you can see in the following tables, students consistently missed the same problem throughout this study. The tables display the total number of student arithmetic errors for each problem on each test.

Total Number of Arithmetic Errors

for Each Item of the Pre-Test

Test Problems	Group 1	Group 2
1) 163 x 48	8	6
2) 27.01 - 1.2	2	7
3) 16.9/2.8	6	8
4) 89 - 15	1	0
5) 120.3 x 13.2	6	9
6) 214.70 + 38.162	1	6
7) 2.4/.12	5	5
8) 348 + 610	0	0
9) 248.6 + 10.7	1	2
10) 4922 - 130.29	6	9
11) 162/28	13	12
12) 10 x 3	0	0
13) 16 + 21	1	2
14) 810 - 633	2	6
15) 12 x 50	1	0

Table 1. Pre-Test without calculators

Total Number of Arithmetic Errors

for Each Item of the Post-Test

Test Problems	Group 1	Group 2
1) 163 x 48	1	8
2) 89 - 15	1	1
3) 2.4/.12	9	8
4) 4922 - 130.29	2	8
5) 16 + 21	0	0
6) 27.01 - 1.2	0	5
7) 16.9/2.8	4	13
8) 120.3 x 13.2	2	9
9) 214.70 + 38.162	3	3
10) 348 + 610	0	0
11) 248.6 + 10.7	2	2
12) 162/28	4	14
13) 10 x 3	0	0
14) 810 - 633	0	3
15) 12 x 50	1	1

Table 2. Post-Test: Group 1 with calculators and Group 2 without calculators.

Collectively on both tests, problem #11 and #12, $28\overline{)162}$, on the Pre-Test and Post-Test, respectively, were missed most often. Overall, students in Group 1 missed fewer of the problems on the Post-Test than students in Group 2. The problems on the Post-Test which were missed most often by Group 2 were the division problems. On Problem 12, $28\overline{)162}$, fourteen out of nineteen students missed the problem. On the same problem in Group 1, only four out of twenty-two missed problem 12. On problem 7, $2.8\overline{)16.9}$, thirteen out of nineteen missed the problem. On the same problem in Group 1, only four out of twenty-two students missed problem 7. On problem 3, $.12\overline{)2.4}$, eight student out of nineteen missed the problem. On the same problem in Group 1, nine out of twenty-two students missed the problem. Problem 7 was the only problem where students with calculators had a higher error rate.

In this section, the writer discussed the results of calculating the t-test for the null hypothesis, the mean score average of the Pre-Test and Post-Test, the percent of student arithmetic error, and the items missed most often by students on the tests.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

Calculators are part of our every life, and we all need to know how to use them. We begin using them in school and they are a great tool for students. Even though we use the calculator in class and out of class, students still need to know how to accomplish calculations with pencil-and-paper. Yet being human, we make mistakes using both pencil-and-paper and a calculator to compute answers to math problems. The purpose of this study was to determine if middle school mathematics students arithmetic error rate was greater without the use of a calculator or with the use of a calculator.

The two hypotheses for the study were as follows. There will be no significant difference in the student arithmetic error rate between the pre-test and post-test mean scores when not using a calculator. There will be no significant difference in the student arithmetic error rate between the pre-test and post-test mean scores when using a calculator.

The subjects were forty-one seventh grade students of mixed abilities ranging from seventh to ninth grade mathematics. The writer used teacher generated pre-test and post-test to determine the students average mean test score which measured the students arithmetic error rate when not using a calculator and when using a calculator.

The results of this study were as the writer originally proposed. Student arithmetic errors were fewer using calculators. When not using a calculator students made two-and-a-half times as many errors as the students using a calculator. Some of the types of errors were mis-alignment of numbers, incorrect operation used, incorrect algorithm used, mis-placed decimals, not attempting to do the problem and typing an incorrect number into the calculator.

Conclusions

The writer observed that students were very reluctant to choose to use pencil-and-paper to complete a calculation. They were even more reluctant to accomplish mental calculations. Students were extremely eager to use the calculators. Yet when using the calculator, they showed a ten percent error rate.

By far, the division problems gave students the most trouble. Whether they were using a calculator or not. Surprisingly, the problem $28\overline{)162}$ was missed the most often on both tests. The majority of students not using a calculator were unsure of where to place the decimal in the answer. Students also had trouble finding the highest number of times 28 would go into 162. Students using the calculator had trouble with all division problems. They were unsure which number to put into the calculator first when the problem was given in long division form, $28\overline{)162}$. Teachers need to be aware of teaching students the proper way to read a problem so students are familiar with the meaning of each problem.

Some of the other problems that were found in this study were not attempting to accomplish a particular problem, mis-typing numbers into the calculator, completing the wrong operation (example: subtraction instead of addition), not typing all of the numbers into the calculator, mis-placing the decimal in the answer, and improper use of the algorithms.

In recent years with the influx of calculators into the classroom, students seem to depend more on the calculator and less on what is really happening with the numbers and operations they are using and performing.

Recommendations

This study was done on a rather small group of students. The study should be done on a larger scale at a larger school. Research could also be done to compare students arithmetic error rate using mental computation in comparison to computation with a calculator. This type of study would be much harder to conduct as there is really no work when students us mental computation. Yet, the comparison of the two would be interesting.

There is great importance in teaching students the correct algorithms for pencil-and-paper calculations. This is were the foundation for using a calculator correctly begins for students. Teachers should also be aware of the great importance in instructing students to properly use a calculator. Teachers should be conscious of allowing students to see the usefulness of learning all methods for computing the result of a problem. Student understanding of the basic math facts and the proper algorithm to use is extremely crucial for all calculation methods. Research does purport that calculators allow students to dispense with tedious calculations and develop their problem solving skills. Yet teachers must be careful to insure that students are able to accomplish those tedious calculations correctly regardless of the method used.

Appendix A1

Pre-Test

Solve.

1) 163 × 48	2) 27.01 − 1.2	3) 2.8)16.9
4) 89 − 15	5) 120.3 × 13.2	6) 214.70 + 38.162
7) .12)2.4	8) 348 + 610	9) 248.6 + 10.7
10) 4,922 − 130.29	11) 28)162	12) 10 × 3
13) 16 + 21	14) 810 − 633	15) 12 × 50

Appendix A2

Post-Test

Solve.

1) 163 x 48	6) 27.01 - 1.2	11) 248.6 + 10.7
2) 89 -15	7) 2.8)16.9	12) 28)162
3) .12)2.4	8) 120.3 x 13.2	13) 10 x 3
4) 4,922 - 130.29	9) 214.70 + 38.162	14) 810 - 633
5) 16 + 21	10) 348 + 610	15) 12 x 50

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