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ABSTRACT

As part of an effort to improve community college algebra students' ability to solve word problems, a study was undertaken at Florida's Manatee Community College to determine the effects of using heuristic instruction (i.e., providing general rules for solving different types of math problems) in combination with the TI-92 calculator. The TI-92 combines the capabilities of a computer algebra system, which has shown potential in improving students' problem solving ability, and the portability of a calculator. The study involved two sections of basic college algebra students. Although both groups received explicit heuristic instruction, the control group solved equations by hand and the treatment group used the TI-92. Pre- and post-tests were administered to both groups to determine the effects of instruction. Analysis of covariance on post-test scores, using pretest scores as a covariate, indicated that the treatment group scored significantly higher than the control group, but no significant differences were found between males and females. The pre- and post-tests; a scoring rubric; and tables showing mean pre- and post-test scores by group, mean pre- and post-test scores by gender, and an analysis of covariance for post-test scores using pre-test scores as a covariate are appended. Contains 15 references. (HAA)

Running head: USING THE TI-92 TO SOLVE ALGEBRA WORD PROBLEMS

The Effect of Using the TI-92 on Basic College Algebra Students' Ability to Solve Word Problems

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Abstract

Solving word problems remains a difficult task for community college algebra students. Computer algebra systems (CAS) have shown potential to improve students' problem solving ability; however, since CAS require computer labs, few instructors are able to incorporate them into the curriculum. The TI-92 has the capabilities of a CAS and the portability of a calculator. This study investigated whether TI-92 based instruction could improve students' ability to solve word problems. Two College Algebra sections served as groups. Both groups received explicit heuristic instruction, but the treatment group solved equations using the TI-92 while the control group solved equations by hand. Analysis of covariance on post-test scores with pretest scores as covariate revealed the treatment group scored significantly higher than the control group. No significant differences were found between males and females. Further studies which confirm these findings are warranted.

Introduction

The American Mathematical Association of Two-Year Colleges (1995) has recognized that technology has reduced the importance of many paper and pencil algorithms contained in a traditional community college Basic College Algebra (BCA) curriculum. Simultaneously, an increasingly technological world is demanding graduates possess problem solving skills similar to those used while solving algebraic word problems (Preston, 1988). Yet, algebra teachers will readily confirm that word problems remain one of the most vexing topics covered. Therefore, improving students' ability to solve word problems remains a priority for community college algebra teachers.

Background Studies and Definitions

Studies by Schoenfeld (1985) and Collins, Brown, and Newman (1989) strongly suggest that explicit instruction on the use of problem solving heuristics is an effective way to improve students' problem solving ability. A heuristic is a general rule of thumb that can be applied to several types of problems for the purpose of guiding reasoning toward a valid solution (Schoenfeld). Since word problems are one class of mathematical problems, it would be reasonable to include explicit heuristic use as the basis for successful word problem solving instruction.

In addition to heuristic instruction, studies conducted by Heid (1988) and Trout (1993) suggest that instruction which integrates computer algebra systems (CAS) can lead to improved student problem solving ability. CAS are computer programs capable of quickly performing symbolic as well as numeric computations—specifically, CAS can solve equations entered by the student (Bollinger, 1989). CAS-based instruction would appear to have great potential to change algebra word problems instruction; however,

several other studies suggest that in order to be effective, CAS needed to be available to each student in the classroom as well as on homework (e.g., Cunningham, 1991; Smith, 1994). Furthermore, the recent publication of the Third International Mathematics and Science Study indicates that 77% of all community college faculty still rely primarily on the lecture mode of instruction (Garner, 1997). Therefore, it would appear that even though CAS may improve problem solving instruction, community college instructors would still be unable or unwilling to adopt the method.

A method of instruction that has been widely adopted into the community college mathematics curriculum is the use of scientific calculators (Watkins, Albers, & Loftsgaarden, 1993). This acceptance may be due to the ease in which a calculator can be used in classrooms, on homework, and on tests without drastically departing from a lecture format of instruction. Therefore, a device which had the computation ability of a CAS and the portability of a scientific calculator would be an ideal candidate for word problem solving instruction. The Texas Instruments TI-92 is one such device.

Purpose

The purpose of the present study is to investigate whether instruction which combines heuristic instruction and TI-92 use is more effective than heuristic instruction alone on improving community college BCA students' ability to solve word problems.

Method

To carry out this investigation, two intact sections of BCA at a community college were involved in a quasi-experiment comparing two instructional methods for solving word problems. The control group was taught via heuristic-instruction alone while the treatment group was taught via heuristic-instruction along with the use of a TI-92.

Participants

During the spring of 1997 a 1:00 PM section of BCA was randomly chosen to serve as the treatment group and a 10:00 AM section was randomly chosen to serve as the control group. Both sections were taught by the author and both sections met Monday, Wednesday, and Friday. Students received extra credit points for participating in the study and were given the option of withdrawing at any time. The treatment group started with 23 and finished with 16 participants and the control group started with 25 and finished with 22 participants. All students who withdrew from the study also withdrew from the class for reasons not related to the study.

Design

A nonequivalent control-group design was used since the random assignment of participants was not possible. The dependent variable is word problem solving ability as measured by a post-test. To control for previous word problem solving skills a parallel form pretest was used as a covariate. The main independent variable was method of instruction. Gender was also included as a second independent variable to investigate whether the main instruction effect was moderated by gender.

Instruments

The author designed a pretest and post-test as parallel forms of the same test. Both forms included problems of the type covered during class and on homework. Both tests consisted of ten questions similar to those covered in a typical BCA textbook and both tests are included as appendices A and B. Since problem solving is considered a process which involves more than simply finding an answer, a scoring rubric was developed for awarding partial credit. The rubric is based roughly on the work of Malone, Douglas,

Kissane, and Mortlock (1980) as well as the work of Austin, Dedrick, Thompson, and White (1996) and is included as appendix C. The rubric awards zero to four points based on the success students had in applying the heuristics included in the instruction.

To address the validity of the pretest and post-test, two experienced BCA instructors inspected the tests and found that the content of the pretest and post-test to be valid measures of students' BCA-level word problem solving knowledge. To address the validity of the scoring rubric the same professors inspected the rubric and found that the content of the rubric was a valid means for measuring success during problem solving.

The researcher and another BCA instructor graded the pretest and the post-test using the rubric as a guide. Inter-rater reliability coefficients for the pretest and the post-test were found to be 0.93 and 0.97 respectively. Since these are adequate measures of reliability between graders (Gall, Borg, & Gall, 1996), a mean score was obtained for all future analyses. To measure the internal reliability of the pretest and post-test, Cronbach's alpha reliability coefficients were computed for the pretest and post-test and were found to be .78 and .84 respectively. These are considered acceptable reliability coefficients given the number of questions and the size of the groups (Gall, Borg, & Gall).

Procedures

To measure initial ability at solving word problems, both groups were given the pretest six weeks prior to word problem instruction. Use of the TI-92 was not allowed by any students during the pretest. During the coverage of word problems, a lecture method with ample opportunity for student interaction was used in both sections. Instruction focused on the heuristics for solving word problems suggested in most BCA text books: (a) read the problem, (b) assign a variable, (c) organize the data, (d) write an equation, (e)

solve the equation, (f) check the solution (e.g., Sullivan, 1996). Each group saw the same examples worked during class and each section was assigned identical homework problems. A twenty minute period at the start of each class meeting was devoted to answering students' homework questions and discussing strategies used for solving various types of word problems. After three class periods of exclusively studying word problems, the post-test was given to both groups.

The only difference in instruction between the two sections was the treatment students borrowed TI-92s to use in class, on homework, and on the post-test. Treatment group students were taught how to solve equations using the TI-92 while control group students solved all equations by hand.

Results

Means and standard deviations of pretest scores and post-test scores by group and gender are given in Tables 1 and 2. It is apparent that all students improved dramatically from the word problem instruction. It is also clear from Table 1 that students who used the TI-92 improved more than those who did not use the TI-92. Table 2 suggests that females and males performed similarly on both the pretest and the post-test.

To quantify the amount of differences displayed in Tables 1 and 2, post-test data were analyzed using a 2 (group) x 2 (gender) factorial analysis of covariance (ANCOVA) with the pretest scores as the covariate. Before conducting ANCOVA, it was determined that the data met each of the following necessary assumptions described by Stevens (1986): (a) the observations are normally distributed on the dependent variable in each group, (b) the population variances for the groups are equal, (c) the observations are independent, (d) a linear relationship exists between the dependent variable and the

covariate, (e) the slope of the regression line is the same in each group, (f) the covariate is measured without error.

Results of the ANCOVA are reported in table 3. These results confirm that the group using the TI-92 scored significantly higher on the post-test than the control group after taking initial differences measured on the pretest into account. No significant differences were found based on gender and no interaction effects were found between section and gender.

After adjusting for pretest differences, post-test means for the treatment and control groups were 29.43 and 22.91 respectively. Using these data along with the pooled standard deviation of 7.86 yields an effect size of 0.83 ((29.43 - 22.91)/ 7.86). An effect size of 0.83 is considered "high" (Gall, Borg, & Gall, 1996).

Discussion

Observations

During classes with the treatment group much less time was spent on solving the equations. Using the TI-92 freed up time to conduct a more thorough check. It also became clear from discussions with the treatment group that students were willing to try several times to develop an equation that modeled the problem. By correcting errors that occurred, students developed a "trial and error" attitude that helped clarify flaws in executing the heuristics for problem solving. Discussions with control students revealed that rarely would they conduct such a trial and error method.

Limitations

Limitations which may have affected the results obtained are the use of intact groups, the inclusion of the researcher in the study, and the size of the groups involved.

The use of the pretest as a covariate helped limit the problem of intact groups. However, the inclusion of the researcher and the size of the groups were inherent to the setting of the study. Another potential threat to the validity of this study is the drop-out rate. Generally speaking, weaker students drop out of a class. Since more students dropped out of the treatment group than the control group, the measured effect could have been artificially high. Despite these limitations, the effect size of 0.83 warrants some attention. These results suggest that a TI-92 has the potential to improve the word problem solving performance of BCA students.

Further Research

To further study this potential, a follow-up study is planned with similar structure to that conducted in the pilot study. Random assignment of participants will be included to reduce the threat caused by existing differences between treatment and control groups. Teachers other than the author will be used to reduce the chance of producing preferential instruction for the treatment group. Finally, to increase the statistical power, larger group sizes will be included. It is anticipated that this true experiment will include 150 participants in each of the control and treatment groups.

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Appendix A

Word Problem Pretest

1. Cedric split his inheritance between two investments, one paying 7% and the other paying 10%. Cedric invested twice as much in the 10% investment as in the 7% investment. His combined annual income from these two investments was $4050. How much did Cedric inherit?

2. Jill earned $381.50 in gross wages one week by working 60 hours. If Jill gets paid time-and-a-half for all hours worked in excess of 40 hours, what is her regular hourly wage?

3. Claire deposited a total of $7500 into two simple interest accounts--one paying 5% the other paying 7%. If the amount of interest earned for 1 year was $405, how much was invested in each account?

4. How many gallons of 4% butterfat milk and how many gallons of 1% butterfat milk must be mixed together to get 12 gallons of 2% butterfat milk?

5. Jacob sells cashews for $6 per pound and peanuts for $1.50 per pound. How many pounds of peanuts must he mix with 20 pounds of cashews to create a mixture that he could sell for $3 per pound?

6. John and Randy are each driving a carload of friends to a concert. John leaves first and travels at an average speed of 45 miles per hour. Randy starts an hour later and travels at an average speed of 55 miles per hour. How long will it take for Randy to catch up to John.

7. A milk tank at the creamery can be filled with the main pump in 7 hours. An auxillary pump can fill the same tank in 3 hours. How long would it take to fill the tank if both pumps are used?

8. A box with a square base and no top is to be made from a square piece of tin by cutting out 3-inch squares from each corner and folding up the sides. If the box is to hold 48 cubic inches, what size piece of tin should be used?

9. A motorboat can go 18 miles per hour in still water. If it can go 80 miles downstream and return to the same point in a total time of 9 hours, what is the speed of the current?

10. Reduced fat hotdogs contain 30% less fat than regular hotdogs. If a reduced fat hotdog contains 14 grams of fat, how much fat does a regular hotdog contain?

Appendix B

Word Problem Post-test

1. A school fund has invested some money in two ways: part of the money at 7% interest and four times as much at 11%. Find the amount invested at each rate if the total annual income from interest is $7,650.

2. Joyce earned $412.80 in gross wages one week by working 56 hours. If Joyce gets paid time-and-a-half for all hours worked in excess of 40 hours, what is her regular hourly wage?

3. Casey invested $14,000 in two accounts--one paying 8% and the other paying 6.5% annual simple interest. If the annual amount of interest earned is $1024, how much was invested in each account?

4. How many liters of a 20% alcohol solution and how many liters of a 50% alcohol solution must be mixed to obtain 12 liters of a 30% alcohol solution?

5. How many pounds of coffee costing $6.20 per pound must Justin mix with 18 pounds of coffee costing $5.80 per pound to produce a mixture that costs $6.10 per pound?

6. A Delta jet leaves an airport traveling at an average speed of 240 kilometers per hour. Three hours later, a United jet traveling the same route leaves the same airport traveling at an average speed of 600 kilometers per hour. How long will it take the United jet to catch up to the Delta jet?

7. Scott can cut a field of hay in 4 hours and Troy can cut the same field of hay in 6 hours. How long would it take them to cut the field if they worked together?

8. A box with a square base and no top is to be made from a square piece of tin by cutting out 2-inch squares from each corner and folding up the sides. If the box is to hold 72 cubic inches, what size piece of tin should be used?

9. A motorboat heads upstream a distance of 24 miles on a river whose current is running at 3 miles per hour. If the trip up and back takes 6 hours, what was the speed of the boat in still water?

10. A stereo is on sale for 15% off its regular price. If the sale price is $1275, what was the original price of the stereo?

Appendix C

Scoring Rubric

The following scoring rubric is to be used to score students work on the pretest and on the post-test. This rubric is loosely adopted from the work of Malone, Douglas, Kissane, and Mortlock (1980). The unpublished work of Thompson, Austin, Dedrick, and White at the University of South Florida's College of Education in their assessment of the Lake Gibson Middle School Project was also used as a reference in developing this rubric.

Score of 0: Non-commencement

Non-commencement refers to the inability of the student to begin to make meaningful progress towards the solution of the word problem. Some examples of non-commencement follow.

a. The student leaves the question blank or has work that is meaningless.

b. The student recopies data from the problem, but does not organize it in any meaningful fashion.

c. The student makes a statement unrelated to the mathematical solution in the problem such as "I have no idea."

d. The student copies down a formula which does not apply to the problem.

e. The student assigns a variable to a quantity that is already known.

f. The student writes an equation, but none of the terms of the equation correctly match those of the correct equation.

Score of 1: Approach

The student shows some attempt at approaching the problem, but reaches an early impasse. For example:

a. The student correctly assigns a variable to an unknown quantity and then stops.

b. The student correctly identifies a formula necessary to solve the problem, but fails to implement it correctly.

c. The student is unable to use a variable or an equation, but shows by trial and error s/he has some understanding of what is involved to solve the problem without successfully solving the problem.

d. The student has a picture drawn that conveys some aspects of the problem, but errors exist in its accuracy.

e. The student has a table set up with some accurate data in place, but not all table entries are accurate.

f. The student writes an equation, but only one of the terms of the equation correctly match those of the correct equation.

Score of 2: Substance

Sufficient detail is shown that demonstrates procedure toward a rational solution, but major conceptual errors exist. For example:

a. The student has a completed picture which accurately represents the constraints of the problem but fails to successfully continue further.

b. The student has accurately completed a data table but fails to successfully continue further.

c. The student writes an equation, but only two of the terms of the equation correctly match those of the correct equation.

d. The student has successfully solved the problem using numerical trial and error methods, but has shown no use of a variable or equation.

Score of 3: Result

The problem is very nearly solved, but minor errors produce an invalid solution. The types of errors here can be considered computational, not conceptual.

a. The student has written the correct equation, but has either stopped or made a computational error.

b. The student has written an equation that would have been correct, except s/he used data other than those given in the problem. The student then goes on to correctly solve this flawed equation.

c. The student solve the proper equation correctly, but fails to complete the solution process (e.g. finds one of the unknowns, but fails to do the necessary computation to find the second unknown).

Score of 4: Completion

The student uses an appropriate equation and produces the valid solution. Note it is a mathematical solution we are seeking; if the student fails to "label" the answer with correct units a score of 4 is still given.

Author Note

This study was conducted as a pilot study to a larger study which is scheduled to be conducted in the spring of 1998. The studies are being conducted in partial fulfillment for the Ph.D. dissertation in Curriculum and Instruction with a Mathematics Education Emphasis at the University of South Florida.

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Table 1

Mean Pretest and Post-test Scores by Group

	Pretest			Post-test		
Group	M	SD	n	M	SD	n
Control	8.68	5.03	25	22.48	6.41	22
Treatment	9.85	7.44	23	29.75	7.88	16
All Students	9.24	6.26	48	25.54	7.86	38

Table 2

Mean Pretest and Post-test Scores by Gender

	Pretest			Post-test		
Gender	M	SD	n	M	SD	n
Female	9.52	6.42	26	25.15	7.94	22
Male	8.91	6.20	22	26.09	7.96	16
All Students	9.24	6.26	48	25.54	7.86	38

Table 3

ANCOVA for Post-test Scores with Pretest Scores as Covariate

Source	SS	df	MS	F	Significance
Within + Regression	1058.82	33	32.09		
Regression	728.04	1	728.04	22.69	.000
Group (G)	402.28	1	402.28	12.54	.001
Gender (S)	18.00	1	18.00	.56	.459
G by S	.65	1	.65	.02	.888
Model	1225.37	4	306.34	9.55	.000
Total	2284.19	37	61.73		

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