DOCUMENT RESUME

ED 104 724 SE 019 018

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TITLE A Statistical Analysis of the Relative Effectiveness of Two Methods of Teaching General Mathematics to Twelfth Grade Students.
SPONS AGENCY Kern Joint Union High School District, Bakersfield, Calif.
PUB DATE Jan 73
NOTE 11p.; Not available in hard copy due to marginal legibility of original document

EDRS PRICE MF-$0.76 HC Not Available from EDRS. PLUS POSTAGE
DESCRIPTORS *Activity Learning; *Arithmetic; Comparative Analysis; Effective Teaching; *Games; Grade 12; *Instruction; Instructional Materials; Low Achievers; Research; Secondary Education; *Secondary School Mathematics; Statistical Analysis; Student Motivation; Student Testing; Teaching Methods; Test Results

ABSTRACT

The author taught one twelfth-grade general mathematics section (30 students) using a lecture method and two sections (31 students) using commercially available games. After six weeks, achievement of both groups was measured. An analysis of covariance (covariate: grade-point-average) was performed. Students in the lecture section showed significantly greater achievement. The author cautions against over generalizing from this result. (SD)

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A STATISTICAL ANALYSIS OF THE RELATIVE EFFECTIVENESS OF TWO METHODS OF TEACHING GENERAL MATHEMATICS TO TWELFTH GRADE STUDENTS

Presented
by
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January 1973

One of the many problems confronting a high school teacher is the problem of motivation of his students. This problem exists to varying degrees depending on the subject-matter taught, grade level of the student, time of day at which class is taught and, of course, the various teacher-controlled factors. Of these many factors, the method used by the teacher to present the material is of utmost importance in the motivation of students.

Motivation seems to be at a maximum if the students are involved in an activity which is classified by them as "fun." One can observe at any high school dance the so-called "slow-learner" exerting so much effort and expending so much energy that his body is drenched with perspiration. This same student is lethargic in an activity which he classifies as "work." It is understood that the work-fun criterion is but one aspect of the subject of motivation. The idea occurred to the author that perhaps the teaching of Math 12, a general mathematics course offered to senior students at North High School, could be improved, in terms of motivation, by using games instead of the lecture method to teach the subject.

A grant of $500 was made available by the Kern High School District for the purpose of comparing, statistically, the teaching effectiveness of two methods of teaching Math 12; games method and lecture method.

After making an exhaustive survey of commercially available games involving fundamentals of mathematics, the following games were purchased:

TABLE I

Games Purchased

Name of Game	Cost	Name & Address of Manufacturer
1. Make One	1.50	Garrard Publishing Co.
2 Say-It: Multiplication	2.50	Champaign, Illinois 61820
3. Addition: Orbiting the Earth	3.00	Scott Foresman
4. Subtraction: Orbiting the Earth.	3.00	855 California Avenue
5. Multiplication: Orbiting the Earth.	3.75	Palo Alto, Calif. 94304
6. Division: Orbiting the Earth.	5.04	
7. Polyhedron-Rummy	1.50	
8. I Win, Set 3	6.75	
9. Here-to-There	4.50	
10. Cal-Q-Late	2.70	
11. Dial The Facts 13	1.65	
12. Dial The Facts 15	1.65	
13. Dial The Facts 16	1.65	
14 Multifacto/Producto	2.70	
15. Playing Card Number Games	55.00	D.C. Heath & Co.
16. Domino Number Games	55.00	Elhi Division
17. Spinner Number Games	55.00	1050 Northgate Drive San Rafael, Calif. 94903
18. Basis	2.00	Holt, Rinehart and Winston, Inc.
19. Wff'n Proof I	5.00	383 Madison Avenue
20. On-Sets	5.00	New York City, New York
21. Wff	1.50	
22. The Real Numbers Game	2.00	
23. Tri-Nim	4.00	
24. Wff'n Proof II	8.00	
25. Twin Choice, Decks 1-8	14.40	
26. Come Out Even, Decks A & B	3.60	
27. The Magic Multiplier	4.44	
28. Cubacus	9.09	

TABLE I Continued

Games Purchased

Name of Game	Cost	Name & Address of Manufacturer
29. Aritho	3.50	Psychological Services
30. Arithmetic Dominoes	3.50	4502 Stanford Street Chevy Chase, Md.
31. Numo	8.95	Midwest Publications Company, Inc.
32. Ranko	7.95	P.O. Box 307 Birmingham, Michigan 48012
33. Mathematical Bingo	3.50	J. Weston Walch, Publisher Portland, Maine 04104
34. Score Four 3-D Family Game	4.95	Miles Kimball Company
35. Super Roulette	8.95	41 West Eighth Avenue
36. Magnetic Math Multiplier	2.59	Oshkosh, Wisconsin 54901
37. Fraction Learner	2.98	

The preliminary organization for this study was done in the 1971-72 school year and the experiment was started at the beginning of the fall semester 1972-73. It was terminated after six weeks. The second period Math 12 class, numbering over thirty students, was taught by the lecture method. The sixth period and seventh period classes, together numbering more than thirty students, were taught using the games method.

Students taught by the lecture method were showed by the teacher using an overhead projector and screen how to do a particular type of math problem. Then each student was asked to solve a similar type of problem at his desk. Then another problem, similar to the first, was solved by the teacher. Again each student was asked to solve a problem at his desk. Finally, the students were assigned several problems to solve at their desks. After a reasonable amount of time, answers were read to the students. Usually some students would ask that particular problems be solved. This was done. Next class-period, the process was repeated. A test was given to the group each Friday and grades were posted in the classroom each Monday. Graded test papers were returned to the students.

The games-taught group was taught differently. These students were not issued a textbook. Two students, mutually chosen, played one game for two class periods. Then the students would change partners and game. Again they would play for two class periods. Each pair of students would read the directions for the game with some help from the teacher. Tests were not given. Frequently, as many as fifteen different games were being played at one time.

The pairing of students seemed desirable because of the possibility of increased student involvement. Each student of a pair would be required to react more than if he were a member of, say, a three man team. In fact, during a two-period session, four students rather than two, were asked to play one game. In each team, of two students, one would be dominant, the other submissive. It was judged that too many students were passive observers rather than players, so the modified procedure was discontinued.

At the conclusion of the experiment, a paper-and-pencil test was given to the group taught by the lecture method. The games-taught group was given ten games, one problem per game and if either of the two groups had an advantage on the post-test, it was the games-taught group. The problem was written on a paper which was placed next to the game. Students moved from one game to the next on a given signal. To have given a paper-and-pencil test to the games-taught group would have placed this group at a disadvantage to the control group and would have confounded the experiment.

The post-tests and pre-tests given to each group are found at the end of this paper.

Certain independent variables, if ignored, could confound the results of this experiment. For example, if one group were intellectually superior to the second group, then the teaching method used with the superior group would likely "prove superior." Since the students could not be matched on scores of relevant, related independent variables and to statistically equate the two groups, the statistic Multiple-Classification Analysis of Covariance was used to compare the teaching effectiveness of the two methods.

The equalizing, independent variables used were the verbal score on the SCAT, the quantitative score on the SCAT, and the score on the Pre-Test. Scores used were raw scores.

Another relevant, independent variable considered was past performance in courses as indicated by grade-point-average. So each group was again divided into two subgroups: high grade-point-average and low grade-point-average. The median grade-point-average of 1.68 was used in order to place fifteen students in each subgroup.

In order to understand the tables, a brief explanation seems necessary. The post test scores are listed under "criterion variable." The three equalizing variables are referred to as "control variables" or "X variables." "Hi, lec." refers to the high GPA subgroup being taught by the lecture method.

The following null hypotheses were used:

H_1 There is no significant difference between the achievement means of the lecture-taught and games-taught groups in their performance on the post-test after equating on three control measures.

H_2 There is no significant difference between the high grade-point-average sub-groups and the low grade-point-average subgroups in their performance on the post test after equating on three control variables.

H_3 There is no interaction between the four subgroups: high GPA-lecture group, low GPA-lecture group, high GPA-games group, and low GPA-games group following the experimental period after equating on three control measures.

The following tables summarize the experimental data:

TABLE II

Sums and Means of Games-Taught and Lecture-Taught Students Classified According to Grade Point Average.

	Criterion Post-Test Scores				Controls Verbal SCAT Scores		Quant-SCAT Scores		Pre-Test Scores	
	N	Y	$\bar{Y}$	Adj. $\bar{Y}$	X_1	$\bar{X}_1$	X_2	$\bar{X}_2$	X_3	$\bar{X}_3$
Games-Taught										
High GPA	15	970	64.67	62.89	392	26.13	257	17.13	642	42.80
Low GPA	15	840	56.00	58.26	352	23.47	238	15.87	599	39.93
Subtotal	30	1810	60.33	60.56	744	24.80	495	16.50	1241	41.37
Lecture-Taught										
High GPA	15	1190	79.33	81.91	348	23.20	221	14.73	642	42.80
Low GPA	15	1110	74.00	70.99	371	24.73	269	17.93	781	52.07
Subtotal	30	2300	76.67	76.45	719	23.97	490	16.33	1423	47.43
Total	60	4110	68.50	68.50	1463	24.39	985	16.42	2664	44.40

TABLE III

Summary of Raw Score Squares and Crossproducts for Criterion and Control Variables

Measure	Symbol	Total
Post-Test	ΣY^2	316,300
Verbal Score on SCAT	ΣX_1^2	39,233
Quantitative Score on SCAT	ΣX_2^2	17,931
Pre-Test	ΣX_3^2	150,604
Crossproducts	ΣYX_1	104,830
	ΣYX_2	70,390
	ΣYX_3	194,390
	ΣX_1X_2	25,059
	ΣX_2X_3	48,415
	ΣX_1X_3	68,051

TABLE IV

Deviation Values for Sums of Squares and Crossproducts

Source of Variation	Σy^2	Σx_1^2	Σx_2^2	Σx_3^2	Σyx_1	Σyx_2	Σyx_3	Σx_1x_2	Σx_2x_3	Σx_1x_3
Teaching Method	4001.66	10.41	0.41	552.06	-204.17	-40.83	1486.33	2.09	-15.17	-75.83
GPA Subgroups	735	4.81	14.01	153.60	59.5	-101.50	-336	8.21	46.40	-27.20
Interaction	41.68	66.17	74.84	552.08	52.5	55.83	151.67	53.93	203.23	191.09
Within	29,986.66	3,478.79	1671.32	31,064.66	4706.67	3004	10,604	977.19	4446.54	3005.74
Total Group	34,765	3,560.18	1760.58	32,322.40	4614.5	2,917.50	11,906	1,041.42	4681	3093.80

TABLE V

Deviation Values for Sums of Squares and Crossproducts, Combined with Within

Within Plus	Σy^2	Σx_1^2	Σx_2^2	Σx_3^2	Σyx_1	Σyx_2	Σyx_3	Σx_1x_2	Σx_2x_3	Σx_1x_3
Teaching Method	33,988.32	3489.20	1671.73	31,616.72	4502.50	2963.17	12090.33	979.28	4431.37	2929.91
GPA Subgroups	30,721.66	3483.60	1685.33	31,218.26	4766.17	2902.50	10268	985 40	4492.94	2978.54
Interaction	30,028.34	3544.96	1746.16	31,616.74	4759.17	3059.83	10755.67	1031.12	4649.77	3196.83

TABLE VI

Analysis of Covariance Significance Tests

		RESIDUALS		
Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Teaching Method	1	4393.180	4393.180	11.117[a]
GPA	1	1296.603	1296.603	3.281
Interaction	1	520.221	520.221	1.316
Within	53	20,943.763	395.165	

a) Significant beyond 0.01 level

For teaching method, $F_{1,53} = \frac{4393.180}{395.165} = 11.117$ (sig.)

For G.P.A., $F_{1,53} = \frac{1296.603}{395.165} = 3.281$ (not sig.)

For Interaction, $F_{1,53} = \frac{520.221}{395.165} = 1.316$ (not sig.)

Conclusions:

1. H_1 must be rejected due to an $F_{1,53}$ value of 11.12. This value is significant at the one percent level. The lecture method of teaching Math 12 was superior to the games-method approach as used in this experiment. The lecture-taught group was superior to the games-taught group on one control variable: the pre-test, but was inferior on two control variables: the verbal score and quantitative score on the SCAT. The differences in scholastic achievement between the two groups were reduced by the control variables to the extent of rendering the two groups equal with respect to the three control variables.

2. H_2 is tenable with an $F_{1,53}$ value of 3.28. This value is not significant even at the five percent level. So those students with high grade-point-averages did not perform significantly better than those students having low grade-point-averages. They did, however, perform better.

3. H_3 is tenable with an $F_{1,53}$ value of 1.32. This value is not significant at the five percent level. Therefore, neither of the subgroups performed significantly better than the others on the post-test in relation to the results in #1 above, i.e., each subgroup had an adjusted average Y score as expected.

4. Forty students out of a total of sixty-three (63.5%) received a lower GPA during the junior year as compared with the sophomore year. Twenty of the forty were in the lecture-taught group; twenty in the games-group. Of the forty students decreasing in GPA, nineteen (47.5%) were male and 21 (52.5%) were female.

5. Nineteen students out of a total of sixty-three (30.2%) received a higher GPA for the junior year as compared with the sophomore year.

6. Four students out of a total of sixty-three (6.3%) received the same GPA for the junior year as for the sophomore year.

7. Twenty-four students had no record of taking the SCAT 3A.

Opinions:

1. Though the lecture method of teaching Math 12 proved superior to the games method, the latter method does have merit. Pressure during the experiment from the teacher was very low and, after the experiment, unexcused tardiness and absenteeism increased in the games-taught group. This situation was not apparent in the lecture-taught group.

2. Perhaps the results of this study could have been reversed if recognition were given by the teacher to game winners in the form of an award. The manner of implementing the games method of teaching is of extreme importance in the effectiveness of the approach and has not been solved as of this writing

3. The type of game used was a factor in the results. Some games were so simple as to be boring to the students. Games judged to be this type are as follows: #3, #4, #5, #11, #12, and #13. Other games, too difficult to comprehend and therefore incapable of motivating the students (or teacher) are #19, #20, #21, #22, #23, and #24. Most of the currently available, commercial games are less than adequate to motivate Math 12 students.

4. Too many students (63.5%) have a tendency to become indifferent concerning academic achievement. Because half of the forty students decreasing in GPA were in the lecture-taught group and half in the games-taught group, it was assummed that decreasing interest in learning was not a significant factor in the outcome of the experiment. If the reason(s) for a growing indifference for excellence could be determined and corrected, then the method used in teaching would assume a role of lesser importance. The counseling department should be assigned the task of determining the GPA trend of each student, including grades of "F" in this determination. If the majority of students are receiving lower GPA each successive year, then the district should attempt to correct the situation. The author is not aware of any effort to correct any apparent mental lethargy of the students.

5. Motivation in the games-taught group was much less than had been anticipated. Many students reverted to socializing rather than playing the game. This fact means that the game, per se, was not capable of motivation. Before discarding the games method, however, several modifications should be tried: improvement of the game, development of a system of peer-group recognition, development of team play in which dominance-submissiveness are eliminated, and improvement of learning game rules.

6. This experiment has not proved that games should not be used in the teaching of Math 12. This experiment has proved that the games method, as used in this experiment, should not be used exclusively in the teaching of Math 12.

Resume of Post Test Used With
The Lecture-Taught Group

1. A farmer had animals weighing 7 pounds, 8 pounds, 9 pounds, 10 pounds, 11 pounds, 12 pounds, 15 pounds, and 19 pounds. He sold them at $3.00 per pound. On another occasion the weights of the animals were 12, 14, 17, 23, 25, and 16 pounds. This time he received $4.00 per pound for them. Then he sold chickens at $.50 per pound. Their weights were 3, 5, 6, 4, 2, and 7 pounds. He gave his son $2.00 for each animal sold. Find the amount of money he had from the sales after paying his son.
   Equivalent problem:
   $3(7+8+9+10+11+12+15+19) + 4(12+14+17+23+25+16) + 0.5(3+5+6+4+2+7) - 2(20)$

2. A farmer owned one animal weighing 10 pounds, and second weighing 5 pounds, three animals at 9 pounds each, one at 15 pounds and two animals at 11 pounds each. If the total "water weight" of 5 pounds had to be subtracted to find the true weight, what was the total, true weight?
   Equivalent problem:
   $10 + 5 + 3(9) + 15 + 2(11) - 5$

3. Find the total points earned by one student on five tests if the scores were as follows: 63½, 33 and 1/3, 12½, 16 and 2/3, and 8 and 1/3.
   Equivalent problem:
   62½ + 33 and 1/3 + 12½ + 16 and 2/3 + 8 and 1/3

4. Subtract 5 and 7/8 from 12 and 1/3.
   Equivalent problem:
   12 and 1/3 - 5 and 7/8

5. What is the sum of 0.166, 0.083, 0.333, 0.25, 1.666 and 0.67?
   Equivalent problem:
   0.166 + 0.083 + 0.333 + 0.25 + 1.666 + 0.67

6. Pencils sell at 2 for $0.05. How many pairs of pencils are in 12 pencils?
   Equivalent problem:
   $\frac{12}{2}$

7. Four boards have widths as follows: 1¼ inches, 2½ inches, 3 and 5/8 inches and 4 and 1/8 inches. Find the total width.
   Equivalent problem:
   1¼ + 2½ + 3 and 5/8 + 4 and 1/8

8. Subtract the sum of 8,7 and 4 from the sum of 9,8 and 6.
   Equivalent problem:
   (9+8+6) - (8+7+4)

9. What is the sum of 4,3,2 and 1?
   Equivalent porblem:
   4 + 3 + 2 + 1

10. A plumber, who receives $10.89 an hour for his work, works for 35 hours. How much money does he receive?
    Equivalent problem:
    35($10.89)

Resume of Post Test Used With
The Games-Taught Group

1. Game used: NUMBERS UP
   Question: What is the total score?
   Equivalent problem:
   $3(8+7+6+5+4) + 9(8+9+10+11+12) + 2(11+12+13) - (12+13+14+14+15)$

2. Game used: CAL-Q-LATE
   Question: What is the total score if all multiplication is done first?
   Equivalent problem:
   $(9)(7) + (6)(8) - (5)(3) - (2)(9)$

3. Games used: MAKE ONE
   Question: What is the total percentage?
   Equivalent problem:
   16 and 2/3 + 12½ + 33 and 1/3 + 66 and 2/3 + 12½

4. Game used: HERE-TO-THERE
   Question: If the person moved ahead, what would be the number of the new position?
   Equivalent problem:
   $2 + 5/12 + 2/3$

5. Game used: COME OUT EVEN
   Question: What is the sum of the cards in this hand?
   Equivalent problem:
   $5/12 + 4/9 + 2/3 + 5/6 + 3/9$

6. Game used: DIVISION: ORBIT-THE-EARTH
   Question: What arrangement of the dice provides a division problem with a whole number quotient?
   Equivalent problem:
   $45/3 = 15$

7. Game used: SUM IT
   Question: What is the total?
   Equivalent problem:
   $3/8 + 4/6 + 15/16$

8. Game used: EQUALS
   Question: What equation could be formed from these cards?
   Equivalent problem:
   $2 + 7 + 5 = 8 + 6$

9. Game used: SCORE FOUR
   Question: What is the score of this 'win?"
   Equivalent problem:
   $1 + 2 + 3 + 4$

10. Game used: SUPER ROULETTE
    Question: Odds are 17 to 1. The chip is worth $68.49. How much is won?
    Equivalent problem:
    $17(68.49)$