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ABSTRACT

This study examined and refined a mathematics skills instrument used to predict success in an introductory statistics course and to measure improvement in mathematics skills. Alternate forms of a 28-item true-false test were administered as a pretest and posttest to 18 undergraduate and 19 graduate students enrolled in introductory educational statistics courses at the University of Alabama. Cronbach's alpha and corrected item-total correlations were computed for the pretest. Item analysis resulted in the elimination of 10 items from the original instrument. The alpha coefficient for the resulting 18-item instrument was .75. Total pretest scores were correlated with each of three course exams and with course average. Results revealed significant correlations with examinations administered after the first examination for the sample as a whole. However, correlations for the two separate groups revealed significant results only for undergraduates. A groups-by-tests repeated measures design was employed to detect between-group differences and mathematics skills improvement from pretest to posttest. Both groups improved, with greater improvement shown for undergraduates, but no conclusions could be drawn regarding the reason for the improvement. (Author/JGL)

Predicting Success and Measuring Math Skills Improvement in an Introductory Statistics Course

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Presented at the Fifteenth Annual Meeting of the
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ABSTRACT

The purpose of this study was to examine and refine a math skills instrument selected as a screening tool for prediction of statistics success and as a measure of improvement in math skills for students enrolling in introductory educational statistics. Alternate forms of a 28-item true-false test were administered as a pretest and posttest to 18 undergraduate and 19 graduate students enrolled in introductory educational statistics courses during the 1986 summer term. Cronbach's alpha and corrected item-total correlations were computed for the pretest. Item analysis resulted in the elimination of 10 items from the original instrument. The alpha coefficient for the resulting 18-item instrument was .75. Total pretest scores were correlated with each of three course exams and with course average. Results revealed significant correlations with exams administered after the first exam for the sample as a whole. However, correlations for the two separate groups revealed significant results only for undergraduates. A groups by tests repeated measures design was employed to detect between group differences and math skills improvement from pretest to posttest. Both groups improved, with greater improvement shown for undergraduates. The instrument's utility as a predictive tool and as a measure of math skills improvement was discussed.

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Introduction

The math skills of undergraduate students enrolling in introductory statistics courses vary widely. The completion of prerequisite courses is not always a guarantee that students have the entering skills necessary for successful completion of course requirements in statistics. An instrument which is quickly administered and easily graded and which has value in predicting success in statistics would be helpful to instructors in their efforts to advise students as to whether they should attempt the course. Such an instrument would identify those students who do not possess the minimum skills necessary to master course material, as well as those students who may need extra help initially with math operations.

With the establishment of the core curriculum at the University of Alabama, an additional use for a math skills test has developed. The undergraduate statistics course within the area of Behaviorial Studies in the College of Education has been granted a math designation. This means that students successfully completing the course receive credit toward their math requirement needed for graduation. While a course syllabus can be used to document the content of a course, the improvement in math skills as a result of a course can be demonstrated only through student performance. Thus, courses such as introductory statistics which have been granted math designations need instruments which will measure student change in support of the math designation.

The purpose of the present study was to conduct a preliminary investigation of a math skills test which would be of value in predicting success in an introductory statistics course and measuring changes in student math skills from the beginning to the end of the course.

Method

Subjects

Participants in the study were students enrolled in the undergraduate and graduate levels of the introductory statistics course offered by the Area of Behavioral Studies in the College of Education at the University of Alabama. A total of 37 students attending the second Summer term 1986 were included initially. Withdrawals and absenteeism resulted in the loss of nine subjects, yielding a total of 28 students for the final analyses.

Of the 28 students, equal numbers were enrolled in the undergraduate and graduate classes. The undergraduate group consisted of 3 males and 11 females, while the graduate class had 5 males and 9 females. The graduate group was made up almost exclusively of Education majors, but undergraduate student majors varied, including representation from Colleges of Nursing, Social Work, Arts and Sciences, Commerce and Business Administration, Education, and Communication. All students in the undergraduate course were at least juniors. The majority of students in both groups reported limited or no previous computer experience, and only three of the 28 students in both groups had a home computer. Almost all students reported having had at least an algebra course, and over half had taken plane geometry. QPAs of the students ranged from 1.50 to 4.00 on a 4-point scale, with the graduate group's mean QPA of 3.557 (SD=.38) almost a point higher than that of the undergraduate group (Mean=2.68, SD=.60).

Materials

The math pretest used in the present study was one which had been used in past years for judging the level of entering math skills of students in the introductory statistics course. The pretest is an adaptation of a test available elsewhere (Walker, 1934). Although the instrument is more than 50 years old, it was chosen because the items appeared to be appropriate for testing the math skills of interest; specifically, knowledge of the order of operations. These were the skills which, in the opinion of the statistics instructor, had given previous statistics students particular difficulty in mastering the computational aspects of statistics course material. The original test consisted of 24 items, 21 of which were retained. An additional 7 items were included, resulting in a 28-item true-false test (Appendix A) on which students are required to determine whether values on either side of a numerical statement are equalities.

Statistics exams for each course were developed by course instructors. Heavy emphasis was given to computations, use of statistical tables, selection of appropriate statistical analyses, and statistical decision-making. Students were not required to memorize formulae, but they were required to carry out all computations involved in the use of the formulae.

Procedure

Students were given the math pretest at the beginning of the five-week statistics course in which they were enrolled. Following the pretest, they were given a set of rules for order of math operations (Appendix B). Additional data were collected from students on an information sheet (Appendix C) provided at the same time as the pretest. An item analysis was performed on the pretest responses, yielding item difficulties and item discrimination values (based on corrected item-total correlations) which were used as a basis for judging which items to eliminate. The Kuder-Richardson 20 formula (KR-20; Kuder & Richardson, 1937) was used to obtain a measure of the interitem consistency among the 18 retained pretest items, and those items then became the math pretest items used in later analyses. KR-20 is the specialized case of coefficient alpha (Cronbach, 1951) when items are dichotomously scored (Nunnally, 1978).

Math pretest raw scores were computed for each student by summing the number of items answered correctly. Students also received scores on three major statistics course exams, each of which had a maximum point value of 100. Math posttest raw scores were obtained by summing the number of items answered correctly on an alternate form of the revised pretest. The unrevised posttest (containing all 28 items) can be found in Appendix D.

To determine the magnitude and direction of the relationship between math skills and statistics course performance, Pearson product-moment correlation coefficients were computed for the math pretest with exam 1, exam 2, exam 3, and exam average for each of the two groups separately and for the 28 students combined.

Improvement in math skills was assessed through a groups by tests repeated measures analysis of variance design. The use of this design allowed for the examination of differences between groups as well as change from pretest to posttest. This was of particular interest because it was expected that the graduate students, by virtue of their more extensive college experience, would achieve higher pretest scores, and this might affect results.

Results

Item difficulties and item discrimination values were computed for the 28-item math skills pretest results of the 37 students who were administered the test. Several values were used as general guidelines in considering an item for retention or elimination. Chissom, McLean, and Hoenes (1980) have suggested that good items are those with discrimination indices of .40 or greater and difficulty indices between .40 and .70. According to Nunnally (1978), items whose discrimination values equal or exceed .30 are generally considered good.

Item analysis results led to the removal of eight items with the lowest (.10 and below) item-total correlations first. Subsequent analysis resulted in the removal of two more items until 18 items remained. Some of these items had difficulty or discrimination indices falling outside the values suggested above. Such items were examined and then retained to maintain an instrument of adequate length and for which the internal consistency value would not be reduced from that of the original 28-item instrument. Furthermore, as Mehrens and Lehmann (1984) have indicated, there are a number of reasons for retaining items even when discrimination indices are low. A low discrimination index may result because an item is very easy or very difficult, and easy items may be important to retain to aid student motivation. As long as the item discriminates positively, it is contributing to the measurement of student competency. Coefficient alpha for the 18-item instrument was .75, as compared with .73 for the original 28-item instrument. Nunnally (1978) indicated that reliability coefficients of .70 or higher are sufficient for early stages of research. Item analysis results can be found in Tables 1 and 2.

Table 1

Item Analysis Results for 28 Math Skills Items for 37 Students

Item Number	Item Difficulty	Item Discrimination
1*	1.00	****
2*	0.22	0.10
3	0.65	0.62
4*	1.00	****
5*	1.00	****
6	0.81	0.24
7	0.51	0.51
8	0.59	0.25
9	0.32	0.25
10	0.92	0.14
11	0.86	0.19
12*	0.81	0.07
13	0.84	0.42
14	0.86	0.15
15	0.70	0.38
16	0.51	0.24
17*	0.54	0.04
18*	0.78	0.05
19	0.84	0.32
20	0.81	0.15
21	0.46	0.34
22*	0.78	0.04
23	0.86	0.39
24	0.78	0.51
25	0.78	0.40
26*a	0.92	0.19
27	0.81	0.24
28*a	0.65	0.46

* indicates items eliminated.
**** indicates items for which correlations could not be computed.
a. These items were ultimately eliminated because a subsequent item analysis resulted in very low or negative item-total correlations.

Table 2

Item Analysis for 18 Math Pretest Items for 37 students

Item Number	Item Difficulty	Item Discrimination
1	0.65	0.52
2	0.81	0.26
3	0.51	0.52
4	0.59	0.16
5	0.32	0.19
6	0.92	0.22
7	0.86	0.18
8	0.84	0.44
9	0.86	0.23
10	0.70	0.37
11	0.51	0.36
12	0.84	0.36
13	0.81	0.17
14	0.46	0.38
15	0.86	0.44
16	0.78	0.52
17	0.78	0.38
18	0.81	0.24

Correlations and analysis of variance results were based on a total of 28 students; 14 in each of the two statistics classes. Of the 9 students excluded, 5 withdrew from the courses, and 4 were absent from one of the test administrations. Those students who withdrew or were absent did not differ on demographic variables from the 28 students included in the analyses. T-tests revealed that students who withdrew from the course did not differ on pretest results from students who participated.

Math skills pretest scores ranged from 5 to 18 for the 28 students. Their math skills posttest scores ranged from 12 to

18. On exam 1, scores ranged from 67 to 100. For exam 2, the range was 35 to 100, and for exam 3, scores varied from 23 to 100. The average of the three tests ranged from 43.33 to 99. Means and standard deviations on the math skills tests and statistics measures for the 28 students and for the two separate groups are shown in Table 3.

Table 3

<u>Means and Standard Deviations for Math Skills and Statistics Exams</u>

	Undergraduate Course		Graduate Course		Combined Group	
Test	Mean	SD	Mean	SD	Mean	SD
Math Pretest	11.36	3.65	14.07	2.95	12.71	3.54
Math Posttest	15.29	1.68	16.07	2.02	15.68	1.87
Exam 1	90.71	8.11	88.71	9.19	89.71	8.57
Exam 2	75.21	18.23	85.43	15.97	80.32	17.60
Exam 3	75.29	21.42	79.57	20.40	77.43	20.64
Exam Average	80.41	11.96	84.57	13.72	82.49	12.81

The 18-item math pretest yielded a score for each student, obtained by summing correct responses to the 18 items. Math pretest scores were then correlated with each of the statistics exams and with the exam average for students in each of the two courses and for all 28 students combined. These correlations are shown in Table 4.

Table 4

Correlations of Math Pretest Scores with Statistics Measures

Test	Undergraduate Course (N=14)	Graduate Course (N=14)	Combined Course (N=28)
Exam 1	-.26	.33	-.03
Exam 2	.62**	.27	.53**
Exam 3	.65**	.12	.43*
Exam Average	.65**	.24	.47**

* $p < .05$ ** $p < .01$

A significant relationship did not exist between math pretest scores and exam 1 scores for either group. A statistically significant relationship did exist for math pretest scores and exam 2, exam 3, and exam average for the undergraduate class but not for the graduate class. Using math pretest score as the single predictor variable with course average as the criterion, the slope and intercept were computed for undergraduate course students. The prediction equation shown below was the result.

$$\hat{y} = \hat{B}_0 + \hat{B}_1 x = 56.26 + 2.13x$$

Using this prediction equation, the predicted exam average for a student who obtained a score of 6, for example, on the math pretest would be 69.04.

Prior to performing the analysis of variance, the assumptions associated with the design were tested. Testing for homogeneity of variance, it was found that the assumption was not violated. The obtained Fmax value of 4.7 did not exceed the critical value of 6.5 (Fmax, α=.01, k=4, df=13). Tests of additivity revealed violations of this assumption for both groups. For the undergraduate group, an F value of 12.95 was obtained; for the graduate group, the obtained F value was 6.62. Both of these value exceeded the critical value of 4.75 at the .05 level. Despite the violations of the assumption of additivity, the analysis continued as planned since this type of analysis is robust in the face of such violations. The nature of the violation would simply make the statistical test more conservative.

Analysis of variance results are found in Table 5.

Table 5

ANOVA Summary Table for Course-by-Test Repeated Measures

Source	SS	df	MS	F
Course	42.88	1	42.88	3.72
Error Between	299.46	26	11.52	
Test	123.02	1	123.02	41.83
Test x Course	13.02	1	13.02	4.43*
Error Within	76.46	26	2.94	

*$F(1,26) > 4.23$; $p < .05$

Results revealed a statistically significant interaction between course and test. Figure 1 depicts the interaction graphically.

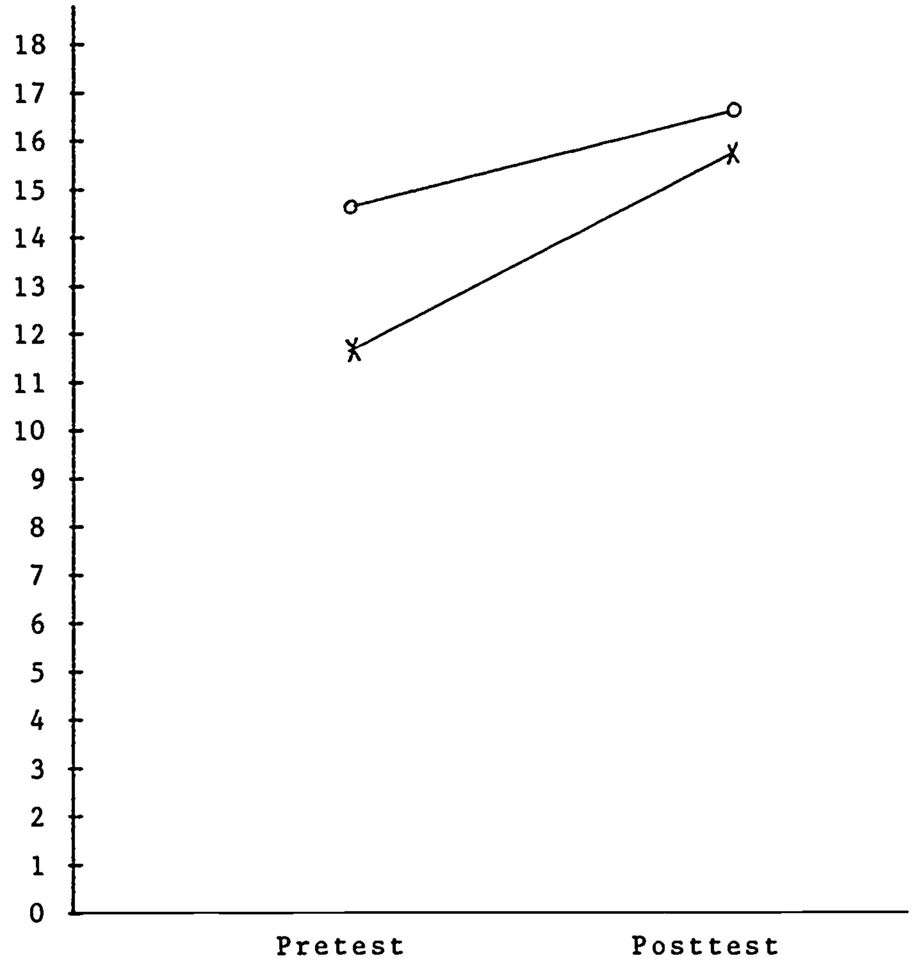

Figure 1. Interaction between groups and measures.

x = undergraduates

o = graduates

15

Since a statistically significant interaction was found, simple main effects were examined. The results of this analysis are shown in Table 6.

Table 6

Simple Effects for Course and for Test

Source	SS	df	MS	Error Term	F
Course					
Course @ Pretest	51.57	1	51.57	6.96	7.41*
Course @ Posttest	4.32	1	4.32	6.96	.62
Test					
Test @ Undergrad	108.04	1	108.04	2.94	36.74**
Test @ Graduate	28.00	1	28.00	2.94	9.52**

*$F(1,54) > 4.03$; $p < .05$ **$F(1,27) > 4.21$; $p < .05$

Results indicated a statistically significant difference between the two groups at pretest but not at posttest. There was also a statistically significant difference between pretest and posttest for both groups. The Eta squared value calculated for the analysis was found to be .32, indicating that 32% of the variability was due to the interaction between groups and tests.

Discussion

Results of the present study indicate that for this group of students, there was a statistically significant relationship between math skills scores and statistics course performance for students in the undergraduate course but not for graduate students. Although the study involved a small sample size, the results provide preliminary evidence to indicate that the revised math skills test has the potential for use in predicting performance in the undergraduate statistics course.

Analysis of variance results do reflect improvement from pretest to posttest for students in both courses, thus providing evidence for the sensitivity of the instrument to change. However, because of the nature of the research design, no conclusions can be drawn regarding the reason for improvement. Further, it is not known whether the change demonstrated in the five-week course will be evident in courses conducted during the regular 16-week school semester.

Research is currently under way using a larger sample for comparison of results with present findings. Item analysis results will be used for revision of the 28-item instrument, and correlations will again be used in an effort to accumulate further evidence of the predictive capabilities of the revised math skills test.

Measurement of math skills improvement is planned which will involve an experimental-control group design, thus addressing the threats to internal validity, such as history (Campbell & Stanley, 1963), not addressed in the present study.

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APPENDIX A

EDP 445
PRETEST*
EDUCATIONAL STATISTICS

INSTRUCTIONS:

Indicate in the blank next to the item whether each statement is true or false.

_____ 1. $3 + 4 + 7 = 7 + 3 + 4$

_____ 2. $3 + 42 \div 5 = 9$

_____ 3. $12(3/4) = 3(12/4)$

_____ 4. $12 \div 3 + 2 = 22/5$

_____ 5. $64 \div (16 \times 2) = 8$

_____ 6. $(3/4)^2 = 9/16$

_____ 7. $(2/3)\ (5/4)\ (3/10) = (2/4)\ (5/10)\ (3/3)$

_____ 8. $25 \div 2 + 3 = 5$

_____ 9. $1/4\ (1 - 3/2) = 1/4 - 3/8$

_____ 10. $\frac{(4 + 8)}{3} = \frac{4}{3} + \frac{8}{3}$

_____ 11. $\frac{(4 + 8)}{(3 \times 2)} = \frac{4}{3} + \frac{8}{2}$

_____ 12. $\frac{(4 \times 8)}{(3 \times 2)} = \frac{4}{3} \times \frac{8}{2}$

_____ 13. $\frac{(4 + 8)}{(3 + 2)} = \frac{4}{3} + \frac{8}{2}$

_____ 14. $\frac{(6 \times 5 \times 7)}{3} = 2 \times 5 \times 7$

_____ 15. $\frac{(4 \times 5)}{3} = \frac{4}{3} \times \frac{5}{3}$

_____ 16. $\sqrt{25 + 16} = 5 + 4$

_____ 17. $5(2 - 1/15) = 10 - 1/3$

_____ 18. $15 \div 3 + 2 = 7$

_____ 19. $\frac{4 + 3}{3} = \frac{4}{3} + 1$

_____ 20. $\frac{36 + 5}{6} = 6 + 5$

_____ 21. $1/2\ (5 \times 7) = (5/2)\ (7/2)$

_____ 22. $6 \div 2 + 1 = 2$

_____ 23. $(7 - 2)^2 = 25$

_____ 24. $3(4 \times 5) = 12 \times 15$

_____ 25. $15 + 9/3 + 3 = 21$

_____ 26. $(17 - 5)/(8 + 4) = 1$

_____ 27. $(2/7)^2 = 4/49$

_____ 28. $7(8 + 2)/(3 + 2) = 14$

* From Walker, Helen, <u>Mathematics Essential for Elementary Statistics</u>.

APPENDIX B

BER-540

Statistical Procedures in Education

EXPLANATION AND RULES*

1. The order in which numbers are added does not affect the result.

2. The order in which numbers are multiplied does not affect the result.

3. If both multiplication and addition (or subtraction) are indicated, the multiplication should be performed first unless parentheses, or other symbols of grouping, indicate otherwise.

4. If both division and addition (or subtraction) are indicated, the division should be performed first unless parentheses, or other symbols of grouping, indicate otherwise.

5. If both multiplication and division are indicated, or more than one division, the expression may be ambiguous unless its meaning is clarified by parentheses or other signs of grouping.

6. Parentheses, braces, and brackets ( ), { }, [ ], may be used to show that whatever is enclosed within them is to be treated as a single number.

7. If the bar of a fraction has the same effect as parentheses, the numerator being treated as a single number and the denominator as a single number.

8. A radical sign has the effect of parentheses, the expression under the radical sign being treated as a single number.

9. In an equation the = is not destroyed if

    a. same number is added to both members
    b. same number is subtracted to both members
    c. same number is multiplied by both members
    d. same number is divided into both members

* From Walker, Helen, Mathematics Essential for Elementary Statistics.

APPENDIX C

Information Sheet

Name:

Address:

Phone:

Student Number:

Major:

Class Standing:

QPA:

Check any of the following math courses you have had either in high school or in college:

- ______ Basic Math
- ______ Algebra
- ______ Plane Geometry
- ______ Solid Geometry
- ______ Trigonometry
- ______ Calculus

In what year was your last math class? __________

What math course (topic) was it? __________

How much experience have you had using computers? (circle one)
None Limited Moderate Extensive

Do you own a home computer? (circle one)
Yes No

APPENDIX D

DER 445/540
POSTTEST
Educational Statistics

NAME: ____________________

INSTRUCTIONS: Indicate in the blank next to the item whether each statement is true or false.

____1. $9 + 6 - 2 = 6 - 2 + 9$

____2. $48 \div 6 + 2 = 6$

____3. $75\left(\frac{2}{3}\right) = 2\left(\frac{75}{3}\right)$

____4. $72 \div 2 + 4 = 12$

____5. $5 + 63 \div 3 = \frac{68}{3}$

____6. $(1/3)^2 = 1/9$

____7. $\left(\frac{3}{8}\right)\left(\frac{1}{6}\right)\left(\frac{4}{5}\right) = \left(\frac{3}{6}\right)\left(\frac{4}{8}\right)\left(\frac{1}{5}\right)$

____8. $48 \div (2 \times 3) = 8$

____9. $\frac{1}{8}(32 + 3) = 4 + 3$

____10. $\frac{9 + 2}{3} = 3 + 2$

____11. $\frac{5 + 7}{(2 \times 3)} = \frac{5}{2} + \frac{7}{3}$

____12. $\frac{(5 \times 7)}{(2 \times 3)} = \frac{5}{2} \times \frac{7}{3}$

____13. $\frac{(5 + 7)}{(2 + 3)} = \frac{5}{2} + \frac{7}{3}$

____14. $\frac{(15 \times 4 \times 7)}{5} = 3 \times 4 \times 7$

____15. $\frac{5 \times 6}{4} = \frac{5}{4} \times \frac{6}{4}$

____16. $\sqrt{36 - 25} = 6 - 5$

____17. $\frac{1}{8}\left(16 - \frac{2}{3}\right) = 2 - \frac{1}{12}$

____18. $25 - 3 + 8 = 30$

____19. $\frac{12 + 2}{3} = 4\frac{2}{3}$

____20. $\frac{48 + 5}{6} = 8 + 5$

____21. $1/3\ (6 \times 4) = 2(4/3)$

____22. $4 \div 2 + 2 = 4$

____23. $(11 - 3)^2 = 64$

____24. $2(5 \times 3) = 10 \times 6$

____25. $12 + 6/2 + 4 = 19$

____26. $(17 + 5)/(8 + 3) = 2$

____27. $(2/8)^2 = 4/64$

____28. $5(6 + 2)/(7 - 2) = 8$

* From Walker, Helen, <u>Mathematics Essential for Elementary Statistics</u>.