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ABSTRACT

It was hypothesized that instruction in descriptive geometry produces an increase in SRT scores. The resultant data do not firmly support this hypothesis. It is suggested that this study be replicated with the use of randomly selected control groups. (MS)

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General Engineering 103 (Engineering Graphics I) is, according to the official description, "an integrated course in engineering graphics for all students in the College of Engineering [p. 99]."[1] A substantial block of time, about five weeks, in General Engineering 103 (GE 103) has been devoted to descriptive geometry. In the process of thinking through the educational objectives of GE 103, the issue of "Why do we teach descriptive geometry?" arose. The traditional rationale for offering instruction in descriptive geometry is stated succinctly, if not behaviorally, in the preface to a popular descriptive geometry text. "This subject is taught ... in almost every engineering school throughout the world for the express purpose of teaching the student to visualize through the development of his ability to analyze and reason [p. 1.]."[2]

The College Entrance Examination Board (CEEB) publishes a "Spatial Relations Test" (SRT), which was developed by the Educational Testing Service (ETS). In a leaflet describing various college placement tests, the CEEB presents the following brief summary of the SRT.

> This is a one-hour objective test intended primarily for students planning to pursue a scientific or engineering program. Scores are particularly useful in predicting grades in engineering drawing courses. No advance preparation by the student is necessary. Forms KPL 1 and KPL 2 are available [p. 9-10].[3]

At first blush it would seem reasonable that the traditional rationale for teaching descriptive geometry might be evaluated, in part, by a statistical analysis of SRT scores obtained from students before and after being taught a unit on descriptive geometry.

Several researchers have reported substantial validity coefficients when older forms of the CEEB-SRT were correlated with engineering drawing grades. For example, Newman et al.[4] found a correlation of .49 between SRT scores and engineering drawing grades for students at the U. S. Coast Guard Academy. In an intensive study of the predictive capabilities of the CEEB-SRT (Form

VAC -1), Blade and Watson[5,6] reported correlations of (a) .36 between SRT scores and first semester engineering drawing grades and (b) .48 between SRT and first semester descriptive geometry grades. Myers[7] noted that CEEB-SRT scores (on both a "pre" and "post" basis) correlated .65 with grades in Military Topography and Graphics.

Disregarding the demonstrated predictive validity (for particular groups) of SRT scores, one might analyze change scores on the SRT as a function of exposure either to a course in engineering drawing or to a part of that course, e.g., descriptive geometry. Indeed, one might guess that such scores would be positively affected by a treatment involving instruction in engineering drawing or, in specific, descriptive geometry. The evidence available indicates just such increases in mean SRT scores. Myers[7] reported a mean increase of 13.2 points ($\overline{X}$ = 53 on the pretest; $\overline{X}$ = 66.2 on the posttest for cadets at the U. S. Military Academy. The time interval between test administrations was one academic year. During that year all subjects (N = 593) were enrolled in an engineering drawing course, Military Topography and Graphics. The <u>same</u> form of the CEEB-SRT was used for both test administrations. In fact, the correlation of scores on the two administrations was .84. Blade and Watson[5,6] also presented "pre" and "post" data for the CEEB-SRT. The subjects were (a) engineering students and non-engineering students at Cooper Union, (b) engineering and non-engineering students at the University of Wisconsin, and (c) cadets at the U. S. Military Academy (these apparently were the same subjects used in the Myers study). Cadets and engineering students at both Cooper Union and Wisconsin received a year's instruction in engineering drawing. Again the <u>same</u> form of the test was used in the "pre" and "post" test administrations. All categories of subjects exhibited a mean gain in SRT scores. However, the mean gain by engineering students was about twice (or greater) the mean gain of the non-engineering students at the same institution.

For example, the mean gain by Cooper Union engineering students was 11.53 while the mean gain for non-engineering students was 4.85. Likewise, the mean gain for University of Wisconsin engineering students was 12.13 and the corresponding gain for non-engineering students was 6.43. As Blade and Watson admitted,[5,6] it seems clear that part of the mean gain in SRT scores is due to practice on the same test. However, the effect of differential recruitment and instruction in other engineering courses may have accounted for some of the greater mean gain by engineering students. From a statistical comparison of the difference between gain scores of Wisconsin engineering and non-engineering students, Blade and Watson concluded that, in large part, "improved test scores are due to engineering training and not to repetition of the test itself ... [p. 6]."[5] Despite the evidence presented by Blade and Watson,[5,6] it has yet to be demonstrated that instruction in engineering drawing and, in particular, descriptive geometry does, in fact, enhance the student's spatial relations perception.

Clearly, an acceptable experimental or quasi-experimental design for measuring (and accounting for) gain scores would need to control for the practice effect. The use of parallel test forms would partly compensate for practice. Moreover, it would be desirable to have a control group of non-engineering freshmen.

Method

As was indicated earlier in this paper the current CEEB-SRT has two forms, both printed within the same booklet. The first form, KPL 1, contains 45 "intersection" items and 35 "block counting" items. KPL 2, the second form, contains 30 "rotation of solid forms" items and 40 items relating to "surface development." In all likelihood the reader is familiar with each of these item types except the "surface development" items. "Surface development" items consist of (a) a three dimensional drawing of an object, a "model", and (b) a "pattern," which "if cut on the solid lines, might be folded inward on the broken lines to have the same shape as the model." The student is required to identify portions on the "pattern" which correspond to those on the "model." No data are readily accessible which would indicate that KPL 1 and KPL 2 are, in fact, parallel or equivalent forms. Even if the forms were statistically parallel, the types of items differ. Thus practice on one form of the SRT might not increase a student's score on the other.

Prior to beginning a unit on descriptive geometry, one or the other of the two SRT forms was administered to the 20 sections in GE 103 during the spring semester of 1968. These 20 sections, which contained about 20 students each, were randomly divided into two groups of 10 sections each. One group was administered KPL 1 of the SRT; the other group was given KPL 2. At the end of the unit on descriptive geometry (about five weeks after the administration of the pretest), a posttest of the SRT was given. It had been planned for half of the group who had taken KPL 1 as a "pre" to take KPL 2 as a "post"; the other half was to take KPL 1 as a "post." Similarly, of the 10 sections who took KPL 2 as a "pre" it was anticipated that five sections would take KPL 2 as a "post" and five sections would take KPL 1 as a "post". Unfortunately, the logistics of test administration were not equal to the planning. The actual administration was as follows: (a) six sections took KPL 1 as a "pre" and as a "post", (b) nine sections were given KPL 2 as a "pre" and KPL 1 as a "post", (c) one section took KPL 2 as a "pre" and as a "post", (d) four sections received KPL 1 as a pretest and KPL 2 as a posttest. Although the use of a control group was suggested (by Hartley and O'Bryant), none could be located.

Results and Discussion

After scoring all tests according to the key, the raw scores were converted into corrected raw scores by subtracting a correction factor from the number of right responses. This was done in accordance with the procedures listed in Appendix B, "Tables of Raw Score Correction Factors," in the Test Administration and Scoring Manual, 1967-1968 of the CEEB College Placement Tests (published by ETS).

In Appendix C of that same manual are conversion tables for converting corrected raw scores into a College Board Score Scale (CEEB with $\bar{X}$ = 500 and S. D. = 100). Because forms KPL 1 and KPL 2 have (a) a different number of items and (b) different norms, it was necessary to convert corrected raw scores into CEEB scores in order to make "pre" and "post" comparisons when both KPL 1 and KPL 2 were used.

Several different analyses were made of the data. First, by use of the correlated data t test technique, "pre" and "post" scores of individuals were compared. In the two situations when different test forms were used, the corrected raw scores were converted to CEEB scores. These data are presented in Table 1. It should be observed that there is a significant mean gain in both test-retest situations. However, there is a significant mean decrement when students were pretested on KPL 2 and posttested on KPL 1. In contrast, students exhibited a mean gain when they were pretested on KPL 1 and posttested on KPL 2. These somewhat contradictory findings are difficult to explain. Judging from the mean CEEB scores, one will notice that KPL 2 appears to be the easier of the two forms. Thus going from an easy test to a difficult test would tend to produce little gain (in fact, a decrease was observed) in mean scores. Likewise, the difference between a difficult test and an easy test would inflate the mean gain. None of the data in Table 1 offer firm support for the hypothesis that exposure to descriptive geometry enhances SRT scores. In the absence of a control group, it is impossible to say more than that some of the gain shown by students taking the same form may be due to practice. The significant gain and the significant loss shown by students taking different forms may have been caused by a test artifact — the non-equivalency of the two forms.

The data were also analyzed by using a separate-sample pretest - posttest quasi-experimental design.[8] In this design two or more randomly equivalent groups are required. One group is measured prior to the treatment (in this case, descriptive geometry), the other group subsequent to the treatment. Campbell and Stanley[8] discuss this design as follows:

> This design is not inherently a strong one .... Nevertheless, it may frequently be all that is feasible, and is often well worth doing. ... While it has been called the 'simulated' before-and-after design..., it is well to note its superiority over the ordinary before-and-after design ... through its control of both the main effect of testing and the interaction of testing with X [the treatment]. The main weakness of the design is its failure to control for history [p. 53].[8]

In this study the time period was so short (five weeks) and the treatment so uniform (almost all subjects were freshmen engineering students) that history was not a serious source of internal invalidity. To apply the separate-sample pretest - posttest design it was assumed that there were no carry over effects from taking one form of the SRT to taking the other form. Thus pretest scores of those students who had taken KPL 1 as a pretest were compared with KPL 1 posttest scores of those students who had taken KPL 2 as a pretest. A similar comparison was made between the scores of students who had taken KPL 2 as a pretest and the KPL 2 posttest scores of students who had taken KPL 1 as a pretest. These data are reported in Table 2. Again, the results were contradictory. On the more difficult form of the SRT (i.e., KPL 1), there was a negligible and non-significant difference between the pretest mean score of one group and posttest mean score of the other group. However, the mean score of the sections taking KPL 2 as a posttest (but not as a pretest) was significantly larger than the mean score of those who took KPL 2 as a pretest (but not as a posttest).

For the data reported in Table 2 the group mean was the unit of analysis. As a partial check, a reanalysis of KPL 1 data, using individual scores as the unit of analysis, verified the results shown in Table 2.

Conclusion

The data presented in this paper do not firmly support the hypothesis that instruction in descriptive geometry produces an increase in SRT scores. The data hint that training in descriptive geometry might augment the ability to "handle" the types of items in Form KPL 2, the "surface development" items and/or the "rotation of solid forms" items. Perhaps these item types are more related to descriptive geometry than the "intersections" and "block counting" items of KPL 1. However, this is only speculation. Mean scores on test-retest situations do increase. However, there is no control group data, as in the Blade and Watson research,[5,6] to suggest whether the gain is due to practice or to being enrolled in engineering — or to both. Of the six separate comparisons reported in Tables 1 and 2, four give results comparable to those of Blade and Watson.[5,6] Two do not.

Prof. R.E. Spencer has suggested that, since there is little evidence about the size or composition of the sample on which the Test Administration and Scoring Manual, 1967-1968 conversion tables are based, it might be advisable to compute a University of Illinois set of "corrected raw scores to CEEB scores conversion tables." This might be done on the basis of the pretest statistics for both KPL 1 and KPL 2. Then "pre" and "post" scores made by the same group of subjects on different forms of the test could be compared using local conversions specific to the data of this study. This analysis is reported in Appendix A.

If Blade and Watson were correct,[5,6] then it is not only engineering drawing but also other engineering courses (and previous high school work) that affect an engineering student's score on the SRT. Thus a replication of this study might well use what Campbell and Stanley[8] call the "separate-sample pretest-posttest control group design." This quasi-experimental design is similar to the design used in this study except that two randomly selected control groups, which do not receive the treatment, are employed. One control group receives the pretest, the other the posttest. For research on SRT these students might be drawn from freshmen chemistry or physics majors. Campbell and Stanley[8] give this design high marks.

> This design receives a perfect score for both internal and external validity.....As far as is known, this excellent but expensive design has not been - [p. 55].[8]

By using of the above design the researcher could control both practice effects and the effect of training in engineering. Moreover, if the researcher could find engineering students who had not taken and were not enrolled in GE 103, then he could more adequately control for the particular effects of teaching descriptive geometry upon SRT scores.

Table 1

FOUR COMPARISONS OF PRE-TEST AND POST-TEST

DATA ON SPATIAL RELATIONS TEST SCORES

Comparison	Measures	Pre-Test	Post-Test	t	P
	Test Form	KPL 2	KPL 1		
A[1]	$\bar{X}$	601.16	563.18	-3.43	P .01 (two-tailed)
	S.D.	84.91	83.66		
	N	116	116		
	r	.52			
	Test Form	KPL 2	KPL 2		
	$\bar{X}$	44.36 (578)[2]	51.00 (625)[2]		
B	S.D.	12.62	11.99	3.68	P .01 (two-tailed)
	N	14	14		
	r	.85			
	Test Form	KPL 1	KPL 1		
C	$\bar{X}$	49.29 (565)[2]	54.06 (596)[2]		
	S.D.	14.93	15.68	4.26	P .01 (two-tailed)
	N	71	71		
	r	.80			
	Test Form	KPL 1	KPL 2		
	$\bar{X}$	585.63	637.85		
D[1]	S.D.	80.20	70.20	4.79	P .01 (two-tailed)
	N	54	54		
	r	.58			

1. Corrected raw scores converted to CEEB scores before computations.

2. CEEB score equivalents as found in the Test Administration and Scoring Manual, 1967-1968 (ETS).

Table 2

A "Separate-Sample Pretest-Posttest Design" Analysis

of Spatial Relations Test Change Scores

Test Form	$\bar{X}$	S.D.	N[1]	t	P
KPL 1 (Pretest)	49.42 (565)[2]	4.45	10	.032	N.S.
KPL 1 (Posttest)	49.49 (565)[2]	5.96	9		
KPL 2 (Pretest)	46.78 (598)[2]	3.41	10	3.23	.01 (two-tailed)
KPL 2 (Posttest)	52.99 (639)[2]	2.71	4		

1. The unit of analysis was section means.

2. CEEB score equivalents as found in the Test Administration and Scoring Manual, 1967-1968 (ETS).

Appendix A

Following the suggestion of Prof. R.E. Spencer (see p. 7 of this report), two comparisons in Table 1 were reanalyzed. To compare KPL 1 pretest scores with KPL 2 posttest scores (for the same group), all KPL 2 pretest corrected raw scores were standardized to CEEB scores. By using these scores as norms, KPL 2 posttest corrected raw scores were converted to CEEB scores. A similar procedure was followed in the KPL 2 pretest - KPL 1 posttest comparison. In that case, the KPL 1 pretest corrected raw scores were standardized to CEEB scores. These pretest CEEB scores were used as norms to convert the KPL 1 posttest corrected raw scores to CEEB scores.

The results of these analyses were similar to those reported in Table 1. There was a non-significant but negative loss between KPL 2 pretest and KPL 1 posttest mean CEEB scores. A correlated t test was used as the statistical technique. The data were: for KPL 2 $\overline{X} = 500$, S.D. = 100; for KPL 1 $\overline{X} = 496.93$, S.D. = 92.6 ($t = -1.03$, $df = 115$, $p > .05$). Even though the statistical test gave non-significant results, the mean scores did decrease in going from the pretest to the posttest, as they did in the analysis presented in Table 1. Between the KPL 1 pretest mean CEEB score and the KPL 2 posttest mean CEEB score there was a statistically significant gain ($t = 2.9$, $df = 53$, $p < .01$). The data were: for KPL 1 $\overline{X} = 500$, S.D. = 100; for KPL 2, $\overline{X} = 551.3$, S.D. = 88.2. Thus converting to local norms for obtaining corrected raw score to CEEB score equivalencies did not alter materially the conclusions presented in the main body of this paper. One should note, however, the great difference in mean CEEB scores when local norms are used rather than published norms.

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