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A Comparison of Cognitive Performance of PSSC and Non-PSSC Physics Students*

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The introduction of new curricula in science and mathematics in the past 15 years has resulted in numerous studies attempting to determine whether a new curriculum experience facilitates student achievement more than an older or more traditional approach. Many experts in the area of curriculum evaluation feel the question of superiority of the "new" or the "old" curricula never will likely be answered since the two types of curricula profess to be attaining different educational goals.

Most curriculum specialists agree that the objectives of both the new and the old or traditional curricula are to impart knowledge and the ability to use that knowledge to solve problems. New curricula proponents, however, feel that their instructional materials not only present a survey of content but also instruct the student how to acquire, evaluate, and retrieve knowledge.

Heath [1] suggested that instead of attempting to carry out comparative curriculum experiments which probably can never answer the question of which is better, attention should be directed to determining characteristics that differentiate between two or more curricula under study. The four questions he felt were pertinent to the study of curricular effects are as follows:

(1) What cognitive abilities are emphasized in these curricula?
(2) What is the distinctive nature of achievement resulting from these curricula?
(3) What is the effect of different courses on student enthusiasm for the subject matter?
(4) How are aptitude and achievement related in various courses?

The present study attempts to answer questions 1 and 4 posed by Heath.

High school physics was one of the first content areas to be affected by the development and implementation of a new curriculum. Studies carried out within the first few years of the existence of the new Physical Sciences Study Committee (PSSC) curricula compared performance of students with these new approaches to the study of physics to students with a traditional physics background using a test designed for one of the curricula. (See, for example, Hipsher.[2]) An improvement in comparative curriculum evaluation was attained with the administration of tests for both the traditional and new curricula as achievement criteria. (See, for example, Heath.[3]) The difficulty with these approaches was and still is the fact that the students with a particular background tend to do better on the test designed specifically to measure

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the type of achievement emphasized in that particular curriculum. Thus, students with a new curriculum do better on measures of new curriculum achievement, while the students with a traditional background do better on tests emphasizing content found in the traditional course.

The *Taxonomy of Educational Objectives-Cognitive Domain*[4] was selected as the scheme for categorizing cognitive abilities. The *Taxonomy* has been widely used in studies as a framework for classifying educational objectives and test items as to cognitive function. An hypothesized hierarchical arrangement of the *Taxonomy* cognitive levels provides for an implicit ordering of cognitive processes by cognitive complexity. The cognitive levels are, moving from simple to complex: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation.

The *Taxonomy* has been used as a framework in developing chemistry achievement tests to measure cognitive performance levels of students with CHEM Study, a new curriculum, and traditional course background. Anderson,[5] utilizing a test consisting of four subtests corresponding to the four lower levels of the *Taxonomy,* found no significant differences in group mean performance on the subtests except in one instance: low-ability students with a conventional course performed significantly better on the Analysis subtest than did the CHEM Study low-ability students.

In a similar study, Herron [6] found a significant difference in favor of the CHEM Study group on the Application Test and a significant interaction between curricula background and intellectual ability on the Analysis test; the CHEM Study high-ability students did significantly better while the CHEM Study low-ability students did significantly poorer on the Analysis test than did the comparable conventional-ability groups. While no studies were found which used the *Taxonomy* to investigate the cognitive performance of PSSC and non-PSSC students, a study by Heath [7] demonstrated that PSSC students do prefer answers to test questions which relate to fundamental principles and investigation while non-PSSC students preferred memory for facts and practical application-type answers to test questions.

Thus, a strong case may be put forward for stating that PSSC students would do better than students with a traditional background on tasks designed to measure more complex cognitive abilities such as the *Taxonomy* processes of Application and Analysis.

On the other hand, the results of the Heath [8] study and the contentions of the new curriculum developers would lead one to suggest that non-PSSC students would do better on a measure of Knowledge which required recall of terminology and facts.

The intent of this study was to attempt to answer two of the questions posed by Heath [9] using samples of students from a new (i.e., PSSC) or traditional (i.e., non-PSSC) physics background. Specifically, the following research hypotheses were tested:

(1) There will be no significance between group differences in the relationship of academic aptitude and cognitive process (Heath Question 4).
(2) There will be a significant difference in favor of the non-PSSC sample on the Taxonomy process measure of Knowledge (Heath Question 1).
(3) There will be significant differences in favor of the PSSC sample on the Taxonomy process measures of Application and Analysis (Heath Question 1).

Method

To test the hypotheses that the new and conventional curricula do lead to a differential development of various cognitive skills, it is necessary to find an instrument that does not penalize the student for a specific curriculum background (e.g., PSSC or non-PSSC). Thompson and Schwartz [10]

recently reported the results of a longitudinal study which indicated that the CEEB Physics Achievement Test meets the above criteria of appropriateness for both PSSC and non-PSSC students. In addition, the test does make an attempt to measure cognitive skills in addition to recall and application of learned formulas. Thus, if the assumption can be made that students who have taken the CEEB Physics Achievement Test provide a representative sample of students taking physics in high schools in the United States, and that the test is equally fair to students from PSSC and non-PSSC curriculums, then performance on sets of items cagetorized by cognitive process will provide a fair test of the above-stated research hypotheses.

Form LAC 2 of the College Entrance Examination Board's Physics Achievement was selected to provide estimates of student cognitive performance. The total population of physics students who had taken Form LAC 2 of the Physics Achievement Test were classified as PSSC, non-PSSC, or not sure on the basis of their response to a question in the test booklet on the type of physics course experience. The answer sheets of random samples of 370 students were then selected from the identified PSSC and non-PSSC populations. The Verbal and Mathematics *Scholastic Aptitude Test* (SAT) standardized scores were obtained for each candidate in the samples to provide measures of academic aptitude. Students whose SAT Verbal and Mathematics scores could not be located were dropped from the statistical analysis. This left 369 students in the PSSC sample and 359 students in the non-PSSC sample.

A member of the ETS staff and the researcher independently classified the 75 items on Form LAC 2 into the *Taxonomy* levels of Knowledge (9 items). Comprehension (17 items), Application (26 items), and Analysis (23 items). No items were found that could be considered measures of the *Taxonomy* levels of Synthesis and Evaluation. Interrater agreement on classification of items into *Taxonomy* levels was 66%. These results compare very favorably with other reports of classification of test items into the *Taxonomy* framework.[11] Disagreement on item classification was resolved by the two raters through a discussion procedure. The answer sheets of the PSSC and the non-PSSC samples of students who had taken Form LAC 2 were then rescored according to item classification scheme to give four separate measures of cognitive ability.

Results

The summary statistics of the PSSC and non-PSSC samples on the relevant measures are presented in Table I. As a group, the PSSC sample had higher means than the non-PSSC sample in all comparisons, except for the Knowledge process comparison where the difference was nonsignificant.

To answer the question posed by Hypothesis 1 of this study, correlations were computed between the SAT Verbal and Mathematics standardized scores and the four cognitive process measures for each sample, independently. These results are presented in Table II. An examination of the correlations indicate that significant and substantial relationships existed between the SAT measures and the four cognitive process scores. Tests of the differences in Fisher Z transformed correlations were carried out with the finding that no significant differences in correlations between scholastic aptitude measures and the cognitive process measures existed for the PSSC and non-PSSC samples.

The existence of a significant relationship between scholastic aptitude and cognitive process measures suggests that the superior performance of the PSSC sample on the process measures could be explained solely by the greater academic aptitude of the PSSC group. Thus, it was decided to test Hypotheses 2 and 3 by adjusting for group differences in academic aptitude by analysis of covariance method developed by Wilks

TABLE I

Means, Standard Deviations, and Tests of Significance for PSSC and non-PSSC group performance on CEEB Physics Achievement Scholastic Aptitude Test and Cognitive Process Measures

Measures	PSSC (N = 369) M	PSSC (N = 369) SD	Non-PSSC (N = 359) M	Non-PSSC (N = 359) SD	t
Physics Achievement Total	31.99	12.52	27.97	13.31	4.20 [a]
Scholastic Aptitude Test					
SAT—Verbal (V)	586.00	99.70	565.00	98.30	2.86 [a]
SAT—Mathematics (M)	662.00	80.31	632.00	95.52	4.58 [a]
Cognitive Process Measures					
Knowledge (9 items)	4.10	2.34	4.00	2.31	.58
Comprehension (17 items)	5.30	3.18	4.50	2.85	3.58 [a]
Application (26 items)	11.40	5.74	9.60	5.38	4.37 [a]
Analysis (23 items)	11.80	4.39	10.20	4.30	4.97 [a]

[a] Significant at the .01 level.

and Cullikson.[12] This analysis procedure uses Chi-square tests derived from a Neyman-Pearson likelihood ratio approach to sequentially determine the tenability of the three fundamental assumptions underlying covariance analysis: (1) equality of standard errors of estimate, (2) homogeneity of within-group regression; and (3) equality of adjusted group means. The results of the analysis of covariances tests are presented in Table III.

TABLE II

Intercorrelations of Scholastic Aptitude Tests and the Cognitive Process Measures [a]

Process Measure	PSSC	Non-PSSC	Z
SAT V and Knowledge	.48	.42	1.00
SAT M and Knowledge	.46	.40	0.99
SAT V and Comprehension	.49	.49	...
SAT M and Comprehension	.56	.50	1.14
SAT V and Application	.57	.57	...
SAT M and Application	.62	.64	0.44
SAT V and Analysis	.53	.59	1.19
SAT M and Analysis	.50	.59	1.74
SAT V and SAT M	.62	.64	0.44

[a] All intercorrelations are significantly different from 0.00 at the .01 level.

The use of the analysis of covariance entails the meeting of two assumptions. For the analysis of the Comprehension measure, the assumption of equal variance could not be met, thus precluding a direct test of the adjusted group means.** Of the three remaining comparisons, two resulted in significant differences. Thus, when scholastic ability was taken into account, the non-PSSC group performed significantly better on the Knowledge measure while the PSSC group performed significantly better on the Analysis measure thus providing partial support for the hypotheses under study.

** The assumption of homogeneity of within-group regression slopes is also presented as a necessary prerequisite before the test of difference between adjusted means is considered valid. However, a recent report of research carried out by Peckham [13] indicates that the fixed-effects analysis of covariance is robust to the violation of the assumption of homogeneous regression slopes except under extreme situations. Thus, the rejection of the assumption of homogeneity of regression for the Application and Analysis process measures was not considered extreme enough to preclude a test of adjusted mean differences.

TABLE III

Summary of Analysis of Covariance PSSC vs. Non-PSSC Candidates on Process Measures

Cognitive Process Measure	Tests of Differences in Variance of Errors of Estimate		Tests of Differences in Slopes of Regression		Tests of Differences in Intercepts of Regression Lines		Adjusted Means	
	df	χ^2	df	χ^2	df	χ^2	PSSC	Non-PSSC
Knowledge	1	0.27	2	0.28	1	9.78 [a]	3.93	4.17
Comprehension	1	7.74 [a]	2	2.73	1	1.78	—	—
Application	1	0.87	2	6.26 [b]	1	3.54	10.81	10.21
Analysis	1	1.61	2	7.77 [b]	1	9.77 [a]	11.43	10.58

[a] Significant at the .01 level.
[b] See footnote **.

Discussion

The intent of this study was to determine if type of curriculum experience was associated differentially with performance of cognitive tasks of different levels of complexity. For if the new curricula does foster the development of more complex abilities to greater extent than the more conventional curricula, a position held by many backers of the new curriculum, then it would be expected that correlations between scholastic aptitude and the process measures group be significantly lower for the PSSC students than for the non-PSSC student on the higher level processes such as Analysis. The sizeable correlations between scholastic aptitude and the *Taxonomy* measures are similar in size to those reported in other studies relating intellectual ability and achievement. These results indicate that scholastic ability was equally important as a determinant of achievement on the derived cognitive measures for both the PSSC and the non-PSSC group.

When academic aptitude was taken into account by the covariance analysis, a differential trend of performance on the cognitive process measures was noted in the direction of that suggested by the hypotheses under study. That is, a significant difference was noted for the Knowledge measure in favor of the non-PSSC sample while the remaining comparisons tended to support the contention that PSSC students do perform significantly better on the more complex cognitive measures. The statistically significant difference noted on the measure of Analysis in favor of the PSSC sample would be expected on the basis of the stated philosophy of the developers of the PSSC curriculum. Thus, one could conclude that the new physics curricula was more successful in developing higher cognitive skills than the more traditional instructional program.

In considering the significant differences observed in the covariance analyses, it is instructive to note the differences in adjusted mean raw scores. For the Knowledge measure, the difference was 0.24 of a raw score point in favor of the non-PSSC group while the adjusted mean score of the PSSC sample was 0.85 of a point higher than for the non-PSSC sample on the Analysis score. These differences, while reliable, are neither large nor striking, thus one must conclude that both types of curricula provide students with the necessary skills to solve tasks from various cognitive levels with roughly the same facility.

In attempting to explain the relatively small differences in cognitive performance, one could take the position that students in the new or the traditional course devote approximately the same amount of time to learning a subject. Under this assumption,

PSSC students would be expected to spend a greater amount of instructional time developing cognitive skills such as Application and Analysis and a lesser amount of time in learning physics Knowledge. Thus, the comparatively good performance of the non-PSSC students on items measuring cognitive processes of Application and Analysis may be a function of a greater familiarity with a particular topic obtained by exposure to a wide range of physics content.

Summary

A study was carried out to compare the cognitive performance of students from a new curricula (PSSC) and from traditional (non-PSSC) curricula. The *Taxonomy of Educational Objectives* was utilized to categorize the items into four categories on one form of the CEEB Physics Achievement Test. The four sets of items provided cognitive process measures for a random sample of students with a PSSC or non-PSSC background. No significant differences in correlations of academic aptitude and the cognitive measures were found between the two groups. Initial results indicated that the PSSC group was significantly higher on three of the four comparisons made. However, when academic aptitude was taken into account, significant results were noted in favor of the non-PSSC students on the Knowledge measure and for the PSSC students on the Analysis measure of cognitive ability. It was concluded that the results essentially supported the position of new curriculum writers that the PSSC instructional materials were more effective in developing higher cognitive process skills.

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