DOCUMENT RESUME

ED 371 671 HE 027 512

AUTHOR Ratcliff, James L.; Yaeger, Patricia M.
TITLE What Are the Coursework Patterns Most Associated with the Development of Quantitative Abilities of College Students with Low Math Skills?
INSTITUTION Pennsylvania State Univ., University Park. Center for the Study of Higher Education.
SPONS AGENCY Office of Educational Research and Improvement (ED), Washington, DC.
PUB DATE Apr 94
CONTRACT R1171G0037
NOTE 42p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS College Instruction; *College Mathematics; *College Students; *Courses; *Course Selection (Students); Higher Education; Intellectual Development; Mathematical Aptitude; *Mathematics Achievement; Mathematics Instruction; *Mathematics Skills
IDENTIFIERS Graduate Record Examinations

ABSTRACT

This study analyzed data to identify courses which have been associated with improved mathematics and quantitative reasoning ability among students who enter college with high verbal skills but low math skills. The study used the Coursework Cluster Analytic Model (CCAM) to analyze the course sequences of students with high verbal and low math skills who showed varying degrees of improvement as demonstrated by nine item-types of the Graduate Record Examination (GRE) General Test. Student transcripts provided the course enrollment data. The transcripts and GRE scores of 5 successive samples of nearly 1,000 graduating seniors at a private comprehensive college provided the raw data for the analysis. Results indicated that taking different patterns of coursework does lead to different types and levels of development. Other findings suggested: (1) the development of general learned abilities did not have an exact one-to-one relationship with departmental categories and all quantitative reasoning development did not occur exclusively in mathematics classes; (2) the development of general learned abilities was not confined to the lower division; (3) there was little formal monitoring and description of the curriculum in terms of general learned abilities at the college-wide or university-wide level; and (4) coursework associated with gains among high ability students was not the same as that associated with gains among low ability students. Extensive tables and graphs detail the study's findings. Contains 11 references. (JB)

WHAT ARE THE COURSEWORK PATTERNS MOST ASSOCIATED WITH THE DEVELOPMENT OF QUANTITATIVE ABILITIES OF COLLEGE STUDENTS WITH LOW MATH SKILLS?

James L. Ratcliff
Professor and Director

and

Patricia M. Yaeger
Research Assistant

Center for the Study of Higher Education
The Pennsylvania State University
403 South Allen Street, Suite 104
University Park, PA 16801-5202

Paper Presented
at the

Annual Meeting of the
American Educational Research Association
New Orleans, Louisiana

April 1994

This research was conducted with support from Project No. R117G10037, U.S. Department of Education, Office of Educational Research and Improvement, Research Division. The views presented are those of the authors.

PROJECT R117G10037
CFDA 84.117G

Introduction

College students benefit from a curriculum that builds upon their skills and abilities (Pascarella and Terenzini, 1991). However, most colleges and universities provide thousands of courses from which to complete undergraduate degree requirements; students select only 35 to 45 of these in order to complete the baccalaureate. A major challenge to curriculum planners and academic advisors is to provide better guidance in selecting coursework that matches student abilities with an appropriately challenging curriculum (Ratcliff, 1993). This task become particularly difficult for students who enter college with specific educational deficits.

Assessment models developed in the 1970s and 1980s were reliant on multiple regression techniques of data analysis and aggregation of results across whole institutions. Such aggregation may mask or understate the effects of college on specific student ability groups and for specific types of general learned abilities (Ratcliff, 1992). Core curriculum prescribe one set of curricular experiences for students regardless of entering ability; without adjustments or modifications, such curriculum may be actually detrimental to learning for students at the lower and higher quartiles of entering ability. Distributional general education requirements give students (and faculty) little guidance as to the coursework appropriate and challenging to the student's background, interests and abilities. Research on what constitutes an effective match between individual student abilities and the educational program aims and expectations may help improve and enhance college effects on student learning.

Students enter college with varying levels of verbal and quantitative skills. These are commonly measured by the Scholastic Aptitude Test (SAT) or the American College Testing Program examination (ACT). Usually students who perform well on the verbal part of these tests also do well on the mathematics section, and those who do poorly on the verbal part tend to do poorly on the mathematics portion. Thus, while verbal and math scores are correlated, this is not the case for all students. There are significant numbers of students who enter college with high verbal skills but with low math skills relative to the institutional norms of entering college students. How to identify coursework appropriate for these students is the focus of this study.

In this paper we use the Coursework Cluster Analytic Model (CCAM) to identify courses which have been associated with improved mathematics and quantitative reasoning ability among students who enter college with high verbal skills but low math skills. Coursework patterns are identified and described; that is, course sequences and concurrent enrollment in different subjects and departments are highlighted. We provide a profile of which students with high verbal and low math backgrounds showed the largest extent of improvement and of the course sequences in which they enrolled. The nine item-types of the Graduate Record Examination (GRE) General Test were used as outcome measures. Student transcripts provide the course enrollment data. The transcripts and GRE scores of five successive samples of graduating seniors at a private comprehensive college provide the basis for analysis. The analysis will provide a model for analyzing the coursework patterns of students entering college with high verbal but low math abilities.

Framework

Ratcliff and others (1988, 1993, 1994) developed an analytic model for identifying course sequences and course combinations associated with gains in learning outcomes. Courses with links to specific measures of learning are grouped together. This model, the CCAM, has been tested for reliability and validity in several institutional types using a variety of pretest and posttest instruments, and has proved to be a reliable and valid tool for linking what students learn with the curriculum in which they enroll. Also, a recent study has shown that the coursework patterns and student learning identified using CCAM are basically stable (reliable) over successive graduating classes at the same institution (Ratcliff, Yaeger and Hoffman, 1994). Its primary purpose is to identify and describe how individual courses work together to build specific types of cognitive abilities and/or content learning. For example, Jones and Ratcliff used the CCAM to test whether a core curriculum was superior to a distributive plan for general education (Jones and Ratcliff, 1992). They found that learning outcomes varied sufficiently within the subsamples of a research university to justify a limited and focused distributional general education program, rather than a prescribed and uniform core curriculum.

Variation in the development of student cognitive abilities is greater within colleges than between them (Pascarella and Terenzini, 1991). In other words, there are greater differences among students in a single institution than there are differences in students across institutions. Therefore, in order to meet the special needs of its student subpopulations, colleges and universities need to examine the relationship between coursework chosen by students and the learning outcomes evidenced in the assessment of general education and general learned abilities. Information about these relationships can be useful in the planning of student advising, course scheduling, curricular reform, faculty instructional development activities, and the selection of assessment methods and measures (Ratcliff, 1992). In particular, advising can be more effective when tailored to the needs of individual students.

Examining special cases, such as students with high verbal and low quantitative skills, can be useful when applying what Astin calls the "talent development conception of excellence ... excellence [that] is determined by our ability to develop the talents of our students and faculty to the fullest extent possible" (Astin, 1991, p. 6). Identifying coursework which may prove effective in remediating the weaker skills of students is one way to develop the students' talents to the fullest extent possible.

Sample

The study involved successive stratified random samples of graduating seniors from a single institution. The study took place at a private, comprehensive college[1] in the northeastern United States. Students projected to graduate during the 1987-88, 1988-89, 1989-90, 1990-91, and 1991-92 academic years were invited to participate in the study. Each sample was stratified to insure that a representative cross-section of entering abilities (as demonstrated by SAT scores), majors and gender was obtained. Students granted permission to examine their SAT and GRE test scores and all transcript data pertaining to their enrollment patterns as undergraduates.

The transcripts and test scores of nearly 1,000 students were analyzed in the combined 5 year Eastern College (a pseudonym) sample. From nearly two thousand courses appearing on the students transcripts, over 900 courses had adequate numbers of students in the sample to perform the analysis. The subpopulation of interest, students with high verbal and low math scores contained 100 students and 252 courses.

Methodology

This study followed the CCAM methodology as described in Ratcliff, Jones, and Hoffman (1992). The SAT verbal score (SAT-V) of each student was regressed on the four GRE verbal item-type scores (Analogies, Antonyms, Sentence Completion and Reading Comprehension). The SAT math score (SAT-M) was regressed on the three GRE quantitative item-types (Regular Math, Quantitative Comparisons, and Data Interpretation). In addition, the SAT total score was regressed on the two GRE analytic item-types (Analytic Reasoning and Logical Reasoning). One form of the GRE was used in each year of sampling; thus, five forms of the GRE were used in the analysis[2]. By regressing the SAT scores on the corresponding GRE item-types, the effects of entering student ability are removed from the each outcome score, as measured by the GRE item-type. The resulting residual scores are used as measures of learning in college on the dimensions assessed. These residuals are averaged for each course in which each student enrolled. Thus, each course is assigned nine mean residual scores based on the nine GRE item-types associated with it.

Next cluster analysis is used to group together courses which have similar scores across the nine item-types. Cluster analysis is a multivariate technique used to reduce the dimensionality of objects (in this case, courses) in a matrix by grouping similar cases together. It is similar to factor analysis in its reductionism. However, factor analysis groups similar variables together, while cluster analysis groups similar cases together, keeping the number of variables constant. Finally, the CCAM uses discriminant

---

[1]Carnegie classification: Comprehensive Institution I

[2]By special arrangement with the Educational Testing Service, one form of an active but soon to be retired form of the GRE was used in each successive group of graduating seniors, thereby minimizing variation caused by the use of multiple forms of the test and insuring that the raw test data and item-type scores would be available to the researchers.

analysis to test the secondary validity of the course groupings (or clusters). Discriminant analysis tells us which course clusters are associated with the largest gains in learning outcomes, tells us which assessment measures explained the most variation in student learning, and tells how well the model succeeded in classifying courses. In the analysis of coursework taken by students with high verbal and low math skills, nearly 92 percent of the courses analyzed were successfully grouped according to the learning outcomes of the students enrolling in them. Significant relationships were found between coursework taken and six of the nine GRE item-types analyzed, including Analytic Reasoning, Regular Math, Quantitative Comparisons, Reading Comprehension, Data Interpretation, and Sentence Completion.

Analysis

The CCAM was applied to the total combined 5 year sample of Eastern College students and the subsample of high verbal, low math ability students. The coursework patterns of the high verbal/low math subsample and the coursework patterns of the total student group were compared. Specific course sequences associated with gains in math ability were identified. Applied science and social science coursework supportive of the development of quantitative skills was identified for the subsample and the total sample. The enrollment patterns of the subsample and the total sample were compared and contrasted with the general education requirements of the institution. Specific recommendations regarding course selection, course requirements and student advising were made based on this analysis.

Coursework is often developed to match a particular ability or knowledge of the students enrolling. For example, "Introductory German," may not be a course for students who have studied German for several years in high school, while "Advanced German" may be intended for them. Implicit in a distributional requirement for general education is the notion that certain courses are more appropriate for some students and not others. Implicit in the idea of a core curriculum is that students of all precollege ability levels, knowledge bases and interests will profit from the study of a fixed set of coursework. If the argument for a core curriculum is correct, then embedded in the wide array of coursework available to students at a college or university using a distributional curriculum should be a set of courses which consistently produces high gains in general learned abilities. That is, if the core curriculum argument is correct, then there will be an implicit set of courses embedded in the wide array of the distributional requirement which are most effective in the development of general learned abilities of students. Prior research (Ratcliff, Yaeger & Hoffman, 1994) indicated that the group of students with high entering verbal skills but low math abilities (hereinafer referred to as the High/Low Group) enrolled in significantly different coursework and showed significantly different gains in the nine types of learning assessed than the students with low verbal skills and high math abilities (the Low/High Group) and the total combined sample. These findings suggested that a core curriculum was not implicit in the Eastern College curriculum, that it would most likely not be associated with improved gains in student learning along the dimensions assessed, and that further analysis of the coursework of the High\Low Group was warranted.

Subgroup information

The High/Low Group consists of 100 students who scored above the median of 500 on the SAT-V and below 520 on the SAT-M, the bottom third of the SAT-M scores. The 100 students in the High/Low group represented 10.4% of the total sample. Figure 1 presents the data on SAT scores for the High/Low subsample.

Correlation of GRE and SAT scores

To control for the effects of the incoming ability of students, the predictive effect of SAT scores were partialled from GRE item-type scores. This mirrors the analysis performed on the full sample. In the Cluster Analytic Model, the SAT sub-scores were used as measures of entering student ability[3]. Prior to regressing GRE item-type scores on SAT scores, it is important to determine the extent to which GRE item-types and SAT sub-scores are correlated. For example, determining whether the GRE item-type, Analogies, has a stronger correlation with SAT Verbal, SAT Math or the total SAT scores will help determine which SAT score should be used in the subsequent regression analysis.

Figure 2 indicates, for the most part, strong, positive relationships between GRE item-types and SAT scores. GRE Verbal item-types were correlated to the SAT Verbal sub-score with r ranging from .21 to .47 for the High/Low group. GRE Quantitative item-types had stronger correlations with the SAT Mathematics sub-score, ranging from .20 to .31 for the High/Low group. GRE Analytic item-types evidenced moderate to strong correlations with the SAT Total score (r= .24 and .33 for the High/Low group). The correlational analysis of this subgroup suggests comparable distribution of general learned abilities among most item-types.

[3]Recall that the CCAM is amenable to the use of most any qualitative or quantitative assessment criteria. The SAT scores were the only precollege measures available to the researchers. Most precise results, in terms of differential effects of coursework, could be derived from a wider array of precollege and graduation assessment measures (Ratcliff, Jones and Hoffman (1992).

Figure 1. Frequency Distribution of SAT-Verbal and SAT-Math Scores - High/Low Group.

Variable	N	Mean	Standard Deviation	Range
SAT-Verbal	100	548.200	35.46	510-710
SAT-Math	100	472.700	33.21	370-510
SAT-Total	100	1020.900	53.05	910-1220

Figure 1. Frequency Distribution of SAT-Verbal and SAT-Math Scores - High/Low Group (continued).

SAT-Verbal Scores - High/Low Group

```
MIDPOINT
SATV   SAT-VERBAL                                       FREQ  CUM.   PERCENT   CUM.
                                                              FREQ             PERCENT
       |
 510   |******************************                    30    30    30.00     30.00
 540   |***********************************               35    65    35.00     65.00
 570   |********************                              20    85    20.00     85.00
 600   |***********                                       11    96    11.00     96.00
 630   |***                                                3    99     3.00     99.00
 660   |                                                   0    99     0.00     99.00
 690   |*                                                  1   100     1.00    100.00
       |
       ----+----+----+----+----+----+----+
           5   10   15   20   25   30   35
```

SAT-Math Scores - High/Low Group

```
MIDPOINT
SATM   SAT-MATH                                         FREQ  CUM.   PERCENT   CUM.
                                                              FREQ             PERCENT
       |
 380   |**                                                 2     2     2.00      2.00
 400   |**                                                 2     4     2.00      4.00
 420   |*****                                              5     9     5.00      9.00
 440   |**********                                        10    19    10.00     19.00
 460   |*****************                                 17    36    17.00     36.00
 480   |***********************                           23    59    23.00     59.00
 500   |*****************************************         41   100    41.00    100.00
       |
       ----+----+----+----+----+----+----+----+-
           5   10   15   20   25   30   35   40
```

Figure 2. Correlation of GRE Item-Types & SAT Scores - High/Low Group.

GRE Item-types	Code	SAT Verbal	SAT Math	SAT Total
Analogies	ANA	0.25980	0.23479	0.32062
Sentence Completion	SC	0.21441	0.18934	0.26184
Reading Comprehension	RD	0.27887	0.11084	0.25578
Antonyms	ANT	0.47247	0.06348	0.35554
Quantitative Comparisons	QC	0.14506	0.24079	0.24768
Regular Mathematics	RM	0.12844	0.31231	0.28135
Data Interpretation	DI	0.21799	0.19575	0.26824
Analytical Reasoning	AR	0.27107	0.23838	0.33040
Logical Reasoning	LR	0.22614	0.14380	0.24117
GRE Verbal	GRE-V	0.49190	0.21703	0.46464
GRE Quantitative	GRE-Q	0.20586	0.33547	0.34759
GRE Analytic	GRE-A	0.30487	0.24914	0.35973
Minimum		0.12844	0.06348	0.24117
Maximum		0.49190	0.33547	0.46464

Intercorrelation of GRE Item-Types

The internal homogeneity of GRE item-types can be measured by comparing the intercorrelation coefficients of GRE item-types. In the Eastern College Sample, the intercorrelations between GRE Verbal item-types were relatively stronger than those between verbal item-types and other GRE item-type scores. Each GRE subscore tended to have higher correlations with the GRE item-types constructing the subscore than with GRE item-types constructing other test subscores. See Figure 3.

Figure 3. Intercorrelation of GRE Item-Types for the Eastern College Combined Sample - High/Low Group.

	ANA	SC	RD	ANT	QC	RM	DI	AR	LR
Analogies	1.00000								
Sentence Completion	0.33262	1.00000							
Reading Comprehension	0.07303	0.12561	1.00000						
Antonyms	0.31766	0.24532	0.19641	1.00000					
Quantitative Comparisons	0.20511	0.23539	0.17059	0.12669	1.00000				
Regular Math	0.14213	0.22500	0.10089	0.09409	0.51995	1.00000			
Data Interpretation	0.26288	0.10031	-0.03856	0.23467	0.16301	0.25217	1.00000		
Analytic Reasoning	0.18103	0.22593	0.34719	0.23815	0.30446	0.32877	0.30481	1.00000	
Logical Reasoning	-0.05449	0.15518	0.21293	0.15359	0.12236	0.23082	0.35673	0.31232	1.00000

For the High/Low subsample, intercorrelations for Verbal item-types ranged from r=.07 (RD/ANA) to r=.33 (SC/ANA). Intercorrelations for Quantitative item-types ranged from r=.16 (QC/DI) to r=.52 (QC/RM). The intercorrelation between Analytic item-types was .31 (AR/LR).

The intercorrelational analyses showed that in all instances, less than 52 percent of the variance in one item-type was explained by that of another. These findings tended to conform to those of Wilson (1985). The GRE item-types while certainly not totally independent, do tend to measure fairly separate and distinct forms of learning.

Performance on the GRE Examination by Subgroup

The High/Low Group performed moderately well on the GRE General Examinations. The High/Low group had a perfect score on Sentence Completion and answered, on average 102 of 186 items correctly on average. See Figure 4.

Figure 4. The Distribution of GRE Scores for Students in the Eastern College Combined Sample - High/Low Group.

Variable	Mean	Standard Deviation	Min	Max	Number of Items
Analogies	10.460	1.97673	5	15	18
Sentence Completion	9.620	1.83556	5	14	14
Reading Comprehension	13.110	3.07448	6	21	22
Antonyms	11.710	2.57923	5	20	22
Quantitative Comparisons	14.460	3.65817	5	22	30
Regular Math	9.440	2.90357	3	16	20
Data Interpretation	5.290	1.97609	1	9	10
Analytic Reasoning	21.070	5.13112	11	34	38
Logical Reasoning	6.750	2.10998	2	11	12
GRE Verbal	44.900	6.06447	30	67	76
GRE Quantitative	29.190	6.48182	10	44	60
GRE Analytic	27.820	6.12724	15	43	50
GRE Verbal (converted)	493.333	58.10127			
GRE Quantitative (cnvrtd)	447.436	74.26586			
GRE Analytic (converted)	506.026	83.68680			

When the theoretical scores (as predicted by corresponding SAT scores) were compared with the students' actual responses, the subgroup showed large proportions of change on most item-types. See Figure 5. The High/Low group exhibited high residuals on all item-types with the exception of Antonyms. While High/Low group residuals ranged from .03 (DI) to .10 (AR), the total Combined Sample residuals ranged from .19 (DI) to .53 (QC), excluding Antonyms (Ratcliff, Yaeger & Hoffman, 1994, p. 73). Students of different levels of ability upon entrance to college strengthened different types of general learned abilities while in attendance at Eastern College. The High/Low subgroup demonstrated very different profiles of change in general learned abilities from the other ability subgroups. The mix of measures in which Low/Low ability students showed change was unlike that in which High/High students demonstrated change. Similarly, High/Low and Low/High students differed from each other and from the High/High and Low/Low students (Ratcliff, Yaeger & Hoffman, 1994).

The variance in the residuals holds implications for the ensuing cluster analysis in that GRE item-types with greater variance will generally play a more significant role in sorting courses into clusters. As was discovered in the analysis of the five individual Eastern College Samples, those GRE item-types with smaller variance play less of a role in discriminating course clusters.

Figure 5. Summary of Regression Analysis of GRE Scores - Eastern College Combined Sample - High/Low Group.

Dependent Variables GRE Item-types on SAT Sub-scores	Code	F Value	Standard Deviation	Adjusted R-squared
Analogies	ANA	7.093	1.9767	.0580
Sentence Completion	SC	4.722	1.8356	.0362
Reading Comprehension	RD	8.264	3.0745	.0684
Antonyms	ANT	28.162	2.5792	.2153
Quantitative Comparison	QC	6.032	3.6582	.0484
Regular Math	RM	10.592	2.9036	.0883
Data Interpretation	DI	3.905	1.9761	.0285
Analytic Reasoning	AR	12.009	5.1311	.1001
Logical Reasoning	LR	6.052	2.1100	.0486
GRE Verbal (raw)		31.282	6.0645	.2342
GRE Quantitative (raw)		12.428	6.4818	.1035
GRE Analytic (raw)		14.567	6.1272	.1205

$p > F = .05$ (except Data Interpretation, $p > F = .0510$)

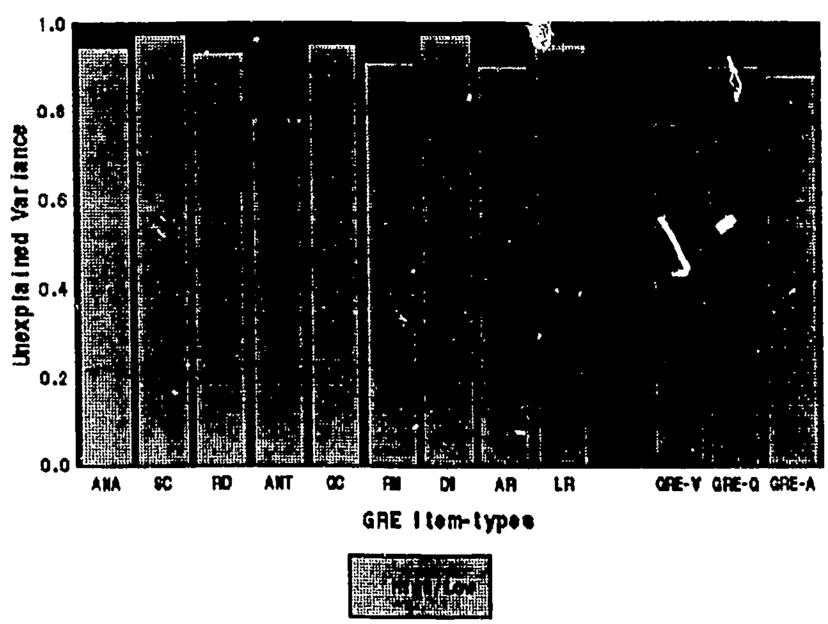
As Figure 5 demonstrates, from nearly 3 percent (Data Interpretation) to 21 percent (Antonyms) of the variation was explained by SAT scores in the High/Low group, demonstrating that the range of residual scores varied considerably across GRE item-types.

Using the student residuals obtained from the regression analysis above, the mean residuals for each course enrolling 5 or more students were calculated for all the 9 GRE item-types. Such a procedure does not assume that the specific gains of the students enrolled in each course were directly caused by that course. Rather, the residuals of each student are attributed to all the courses in which they enrolled, and the mean residuals for each course serve as a proxy measure of student gains. Once courses are clustered by these gains, then hypotheses can be generated and tested as to why students who enrolled in a given pattern of courses experienced significant gains on one or more of the outcomes criteria (i.e., the item-type residuals).

Calculation of mean residuals

GRE item-type scores were regressed on their corresponding SAT subscores. Residual scores are displayed in Figure 6. These scores represent the variance in GRE scores not accounted for by SAT scores. While Figure 5 illustrates proportion of the students' learning attributable to their SAT scores, Figure 6 graphically portrays the residuals not accounted for by the SAT.

Figure 6. Change by GRE Item-type and sub-scores: High/Low Group



Quantitative Cluster Analysis of the High/Low Group

This study used the quantitative cluster analytic procedure of the Cluster Analytic Model (Ratcliff, Jones & Hoffman, 1992) to analyze the High/Low Group. The objects of these analyses are the courses which constitute the enrollment patterns of students in the High/Low Group. Secondary validation (discriminant analyses) of this Group, three other subsamples, and the total Combined Sample suggested that the Cluster Analytic Model was valid and reliable means for determining coursework associated with the general learned abilities of undergraduates (Ratcliff, Yaeger & Hoffman, 1994).

Course-taking Patterns in the High/Low Group

There were 4,146 courses listed on the 100 transcripts of the students in the High/Low Group, indicating that, on average, each of these students had enrolled in an average of 41 courses as part of the baccalaureate degree program; this compares with an average of 43 courses for the total Eastern College Combined Sample. Thus, the high verbal/low math students graduated with slightly fewer credits and courses than the overall sample. There were 1,012 unduplicated courses on the High/Low transcripts, 252 in which 5 or more students had enrolled. These 252 courses were the objects of further analysis for the High/Low Group.

Discussion of High/Low Group residual scores

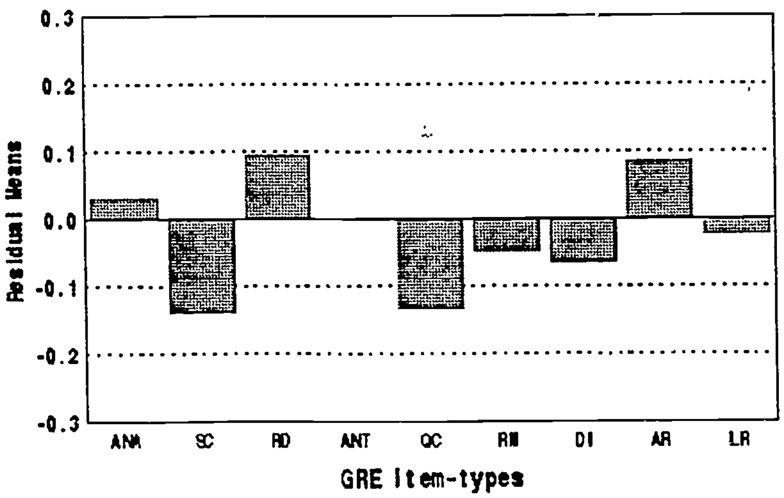
Residuals represent the GRE item-type variance not explained by the corresponding SAT score. Residuals may be positive or negative. If they are positive, they indicate that the student's actual score exceeded its value predicted by the SAT. If the residuals are negative, they indicate that the students performance on the GRE item-types was less than that predicted by the corresponding SAT score. Thus, residuals may express either positive or negative change in general learned abilities.

The average of residuals means for the High/Low Group was negative, indicating that this group showed less overall gain in the general learning measured by the GRE than the overall combined sample. However, the High/Low Group did have positive mean residuals on Analogies, Reading Comprehension, Antonyms, and Analytic Reasoning, (See Figures 7 & 8). This would suggest that these students of high entering verbal ability tended to maximize their strengths in general learned abilities (i.e., verbal skills) over their quantitative abilities. However, these students significantly underperformed their peers on the Sentence Completion and Quantitative Comparisons item-types.

Figure 7. The Distribution of GRE Item-Type Residuals for 252 Eastern College Combined Sample Courses Used in the Qualitative Cluster Analytic Procedure - High/Low Group.

Variable	Number of Items	Residual Means	Standard Deviation	Min Value	Max Value	Std Error of Mean
Analogies	18	0.0297	0.6517	-1.9067	2.9242	0.0410
Sentence Completion	14	-0.1387	0.7241	-1.8062	2.8039	C.0456
Reading Comprehension	22	0.0949	1.0205	-3.5887	3.0882	0.0642
Antonyms	22	0.0007	0.7475	-1.9230	1.9904	0.0470
Quantitative Comparisons	30	-0.1315	1.3899	-5.9188	3.4768	0.0875
Regular Math	20	-0.0464	1.0657	-2.9720	3.6337	0.0671
Data Interpretation	10	-0.0628	0.8219	-3.4915	2.4081	0.0517
Analytic Reasoning	38	0.0869	1.5667	-5.4966	5.9009	0.0986
Logical Reasoning	12	-0.0211	0.7767	-3.7777	2.2063	0.0489
Minimum	10	-0.1387	0.6517	-5.9188	1.9904	0.0410
Maximum	38	0.0949	1.5667	-1.8062	5.9009	0.0986
Mean	21	-0.0209	0.9739	-3.4312	3.1592	0.0613
Total	186					

Figure 8. GRE Item-type Residual Means for High-Verbal/Low-Math Group.



Creating the raw data and resemblance matrices: High/Low Group

Using the mean residuals of the High/Low group and the 252 courses found on 5 or more of their student transcripts, a raw data matrix was created. The data matrix consisted of 252 columns and 9 rows (252 x 9). A resemblance matrix was created next to describe how closely each course resembles the other 251 courses according to the criterion variables: the student score residuals. To calculate the resemblance matrix, the correlation coefficient was selected as a similarity measure (Ratcliff, Hoffman & Jones, 1992; Romesburg, 1984).

Discriminant analysis of coursework patterns: High/Low Group

In examining the dendrogram of the High/Low Group, a logical question arises as to which number of clusters or pattern groupings provides the best explanation of the relationship between student item-type residuals and coursework patterns. Separate discriminant analyses of different numbers of cluster groupings were performed in order to determine the number of groupings that optimizes the proportion of courses correctly classified. Three different cluster solutions provided comparably high levels of correct classification:

9-cluster solution : 91.7% of courses correctly classified
11-cluster solution : 90.9% of courses correctly classified
15-cluster solution : 90.1% of courses correctly classified

While these cluster solutions produced comparable classification results, the different grouping evidenced differing effectiveness in identifying relationships between mean item-type residuals and coursework patterns. The 9-cluster solution proved to provide the greatest extent of information about the relationships between these residuals and coursework patterns and was therefore used in this report.

As in the previous analyses, the discriminant analysis was conducted using the DISCRIMINANT program in SPSSx in the following manner. Discriminant functions were applied to the data using the course item-type attributes as independent variables and the cluster group membership as the dependent variables. The resulting percentage of correct predictions served as a secondary validation of the cluster solution (Ratcliff, Jones & Hoffman, 1992; Romesburg, 1984).

Results of the Cluster Analysis: High/Low Group

The hierarchical cluster structure is presented in the dendrogram of Figure 9. For concise visual presentation, the complex sub-structures of each of the clusters were omitted from the dendrogram in Figure 10. The results of the cluster analysis of the High/Low group are presented in Figure 11. Courses were classified into 9 coursework patterns according to a hierarchical cluster structure.

Using a 9-cluster solution to the quantitative cluster analysis, the largest number of courses are found in Coursework Clusters #2, #5 and #4 with 76, 38 and 35 courses respectively. The smallest cluster is the 9th with one course.

Observations about the clusters: The High/Low Group

As was observed in the other subgroups analyses (Ratcliff, Yaeger & Hoffman, 1994), a careful examination of courses within each cluster seems to indicate that some courses coming from the same department appear in the same cluster, such as the English courses in Cluster #2.

Similarly, there are apparent sequences of courses, such as the AC 105, 106 sequence in Cluster #5. Also, a set of courses coming from various related disciplines may form a homogeneous cluster on the basis of a set of given attributes or criteria, such as the Accounting, Economics, Finance, General Business, and Marketing courses in Cluster #5.

Correlations of item-types and discriminant functions: High/Low Group

The discriminant analysis of the High/Low group provided secondary validation that 91.7% of the classification of courses was correctly predicted by the cluster analysis (See Figure 12). The discriminant analysis is a secondary validation, since it is based on the same sample of transcripts and test scores.

Stated simply, 9.2 of 10 courses most frequently taken by students in the High/Low subsample were correctly classified according to their mean residual GRE scores. While the cluster analysis produced coursework patterns according to criteria of general student learning, additional steps were needed (1) to determine which courses were correctly classified and (2) to ascertain which item-type residual scores contributed to any given coursework pattern.

Using the BREAKDOWN procedure in the DISCRIMINANT program of SPSS-X (Norusis, 1985), courses which were incorrectly classified or which may be classified within another coursework pattern are identified. These courses are marked with a "*" in Figure 11.

To compute the contribution of each mean item-type residual score to the discriminant functions, the correlation coefficients between mean residual scores and discriminant functions were examined. Figure 13 shows the rotated correlations for the 9-cluster solution for the High/Low group coursework.

Figure 9. SPSS-X Dendrogram - High Verbal/Low Math Ability Grouping.

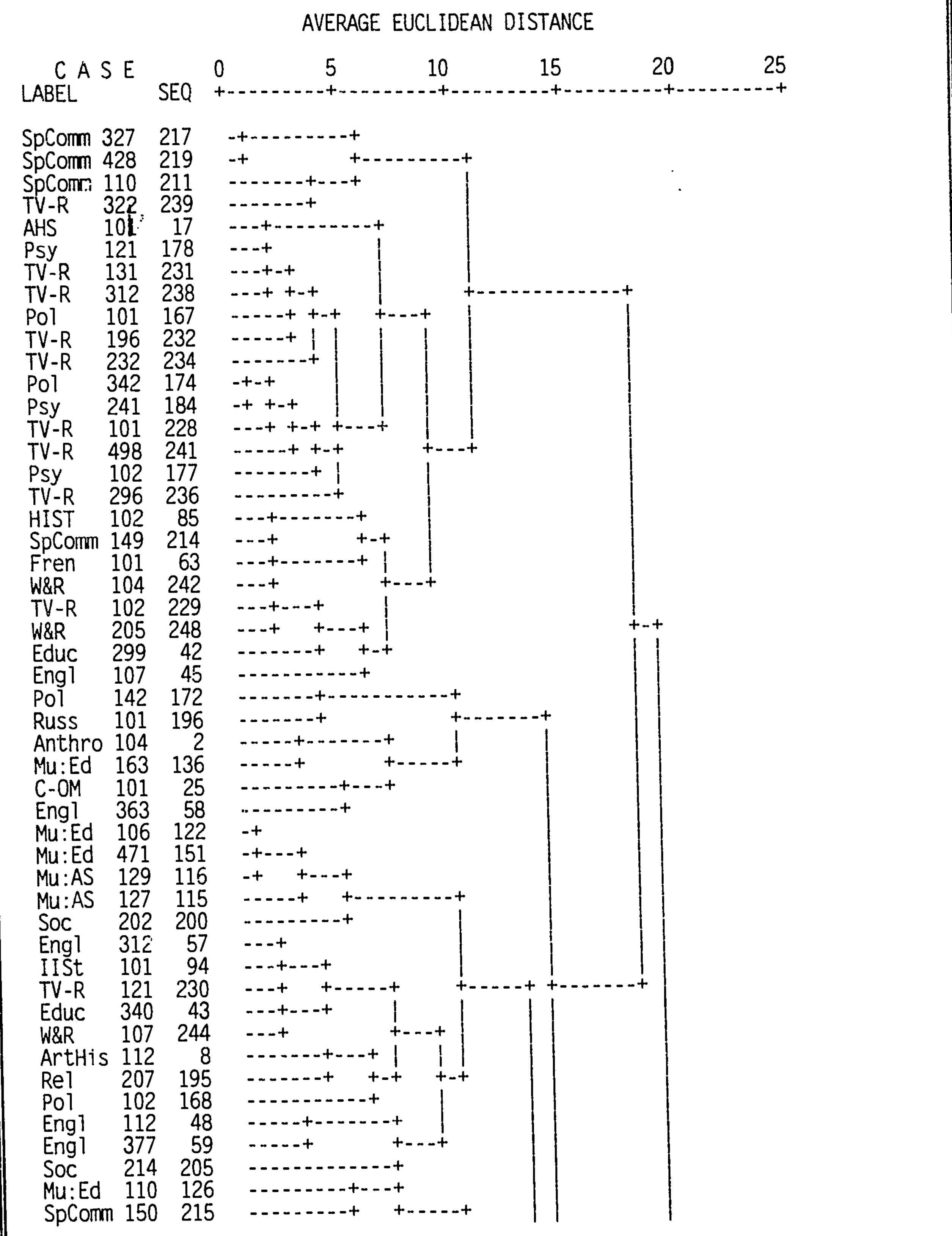


Figure 9. SPSS-X Dendrogram - High Verbal/Low Math Ability Grouping (continued).

```
                         AVERAGE EUCLIDEAN DISTANCE

   C A S E          0         5        10        15        20        25
 LABEL        SEQ   +---------+---------+---------+---------+---------+

 Engl    219   53    ---------+---+     +---+ | |         |
 SpComm  230  216    ---------+         |   | | |         |
 SpComm  140  213    -------------------+   | +-+         |
 Phys    170  160    -+-+                   | |           |
 Span    102  209    -+ +-+                 | |           |
 Engl    110   47    ---+ +---+             | |           |
 SpComm  353  218    -----+   |             | |           |
 Engl    271   55    -+-+     +-----+       | |           |
 Engl    272   56    -+ +---+ |     |       | |           |
 Engl    131   51    ---+   +-+     |       | |           |
 Mu:Ed   109  125    -------+ |     |       | |           |
 Soc     210  204    ---------+     |       | |           |
 Mu:AM   202  109    ---+---+       |       | |           |
 Mu:AS   258  121    ---+   +-+     +---+   | |           |
 Engl    232   54    -----+-+ +---+ |   |   | |           |
 Engl    381   61    -----+   |   | |   |   +-+           |
 Mu:AS   251  120    ---------+   | |   |   |             |
 CP      101   32    -----+-+     | |   |   |             |
 HIST    105   86    -----+ |     | |   |   |             |
 Engl    113   49    ---+-+ |     | |   |   |             |
 Heal    450   83    ---+ | +---+ +-+   |   |             |
 Mu:AS   103  113    -+   +-+   | |     |   |             |
 Mu:AS   104  114    -+-+ | |   | |     |   |             |
 Mu:Ed   368  150    -+ +-+ |   | |     |   |             +---+
 Mu:Ed   107  123    -+-+   |   | |     |   |             |   |
 Mu:Ed   304  145    -+     |   | |     |   |             |   |
 Mu:AS   141  117    -+---+ |   | |     |   |             |   |
 Mu:Ed   367  149    -+   +-+   +-+     |   |             |   |
 Engl    214   52    -----+     |       |   |             |   |
 Mu:AS   101  112    -----+---+ |       |   |             |   |
 Mu:Ed   233  140    -----+   | |       +---+             |   |
 Mu:Ed   166  137    -+       | |       |                 |   |
 Mu:Ed   255  142    -+-+     | |       |                 |   |
 Mu:Ed   232  139    -+ |     | |       |                 |   |
 Mu:Ed   256  143    -+ +-+   +-+       |                 |   |
 Mu:Ed   231  138    -+ | |   |         |                 |   |
 Mu:Ed   303  144    ---+ +-+ |         |                 |   |
 Mu:Ed   234  141    -+-+ | | |         |                 |   |
 Mu:Ed   331  146    -+ | | | |         |                 |   |
 Mu:Ed   133  133    -+ +-+ | |         |                 |   |
 Mu:Ed   134  134    -+ |   +-+         |                 |   |
 Mu:Ed   355  148    -+ |   |           |                 |   |
 Mu:Ed   131  131    -+-+   |           |                 |   |
 Mu:Ed   132  132    -+     |           |                 |   |
 Mu:Ed   332  147    -------+           |                 |   |
 Engl    109   46    ---+---+           |                 |   |
 TV-R    202  233    ---+   +-----------+                 |   |
 TV-R    297  237    -------+           |                 |   |
 Mu:AM   201  108    -----+---+         |                 |   |
```

Figure 9. SPSS-X Dendrogram - High Verbal/Low Math Ability Grouping (continued).

```
                              AVERAGE EUCLIDEAN DISTANCE

   C A S E           0         5         10        15        20        25
 LABEL          SEQ  +---------+---------+---------+---------+---------+

 Mu:AM   301    110   -----+    +-+        |                 |   |
 Mu:Ed   111    127   ---------+ +--------+                  |   |
 Bio     112     21   -----------+                           |   |
 Mu:AM   101    106   ---+-+                                 |   |
 Mu:Ed   113    128   ---+ +-----+                           |   |
 Mu:Ed   108    124   -----+     |                           |   |
 Mu:AS   155    118   -+         +-----+                     |   |
 Mu:AS   156    119   -+-----+   |     |                     |   |
 Mu:AM   401    111   -+     +-+ |     |                     |   |
 Germ    101     67   ---+---+ +-+     +-----------+         |   +-------+
 Mu:AM   102    107   ---+     |       |           |         |           |
 Bio     115     22   ---------+       |           |         |           |
 ArtHis  220     12   -----+-------+   |           |         |           |
 Educ    219     41   -----+       +---+           |         |           |
 Mu:NM   101    152   ---+---+     |               |         |           |
 Thea    140    225   ---+   +-----+               |         |           |
 Fren    201     64   -------+                     +-+       |           |
 Bio     110     20   -+-----+                     | |       |           |
 Psy     311    189   -+     +---+                 | |       |           |
 Phil    102    158   -------+   +-+               | |       |           |
 PhysEd  105    161   -----------+ +-+             | |       |           |
 Psy     321    191   -------------+ +-------+     | |       |           |
 W&R     201    247   ---------------+       |     | |       |           |
 ArtHis  218     11   ---+-+                 |     | |       |           |
 Psy     210    183   ---+ |                 +-----+ +-----+             |
 Thea    363    227   -----+---+             |       |                   |
 Anthro  107      4   -----+   +-------+     |       |                   |
 SPath   100    220   ---------+       +-----+       |                   |
 HIST    101     84   -------+-------+ |             |                   |
 Thea    160    226   -------+       +-+             |                   |
 MRA     102    156   ------- -+-----+               |                   |
 Soc     203    201   ---------+                     |                   |
 Psy     202    180   -------------------------------+                   |
 Mu:Ed   130    130   -------+---+                                       |
 SPath   203    222   -------+   |                                       |
 Ling    233     96   ---+-+     +-----+                                 |
 SPath   202    221   ---+ +---+ |     |                                 |
 Phys    160    159   -----+   +-+     |                                 |
 W&R     106    243   ---------+       +---------------+                 |
 Psy     208    181   -+---+           |               |                 |
 Psy     209    182   -+   +-----+     |               |                 |
 Psy     201    179   -----+     |     |               |                 |
 Psy     308    187   -+---+     +-----+               |                 |
 Psy     309    188   -+   +-+   |                     |                 |
 Psy     316    190   -----+ +---+                     +-------+         |
 Psy     302    185   -----+-+                         |                 |
 Psy     303    186   -----+                           |                 |
 HIST    362     90   ---------+-------+               |                 |
 Math    100     97   ---------+       +-------+       |                 |
```

Figure 9. SPSS-X Dendrogram - High Verbal/Low Math Ability Grouping (continued).

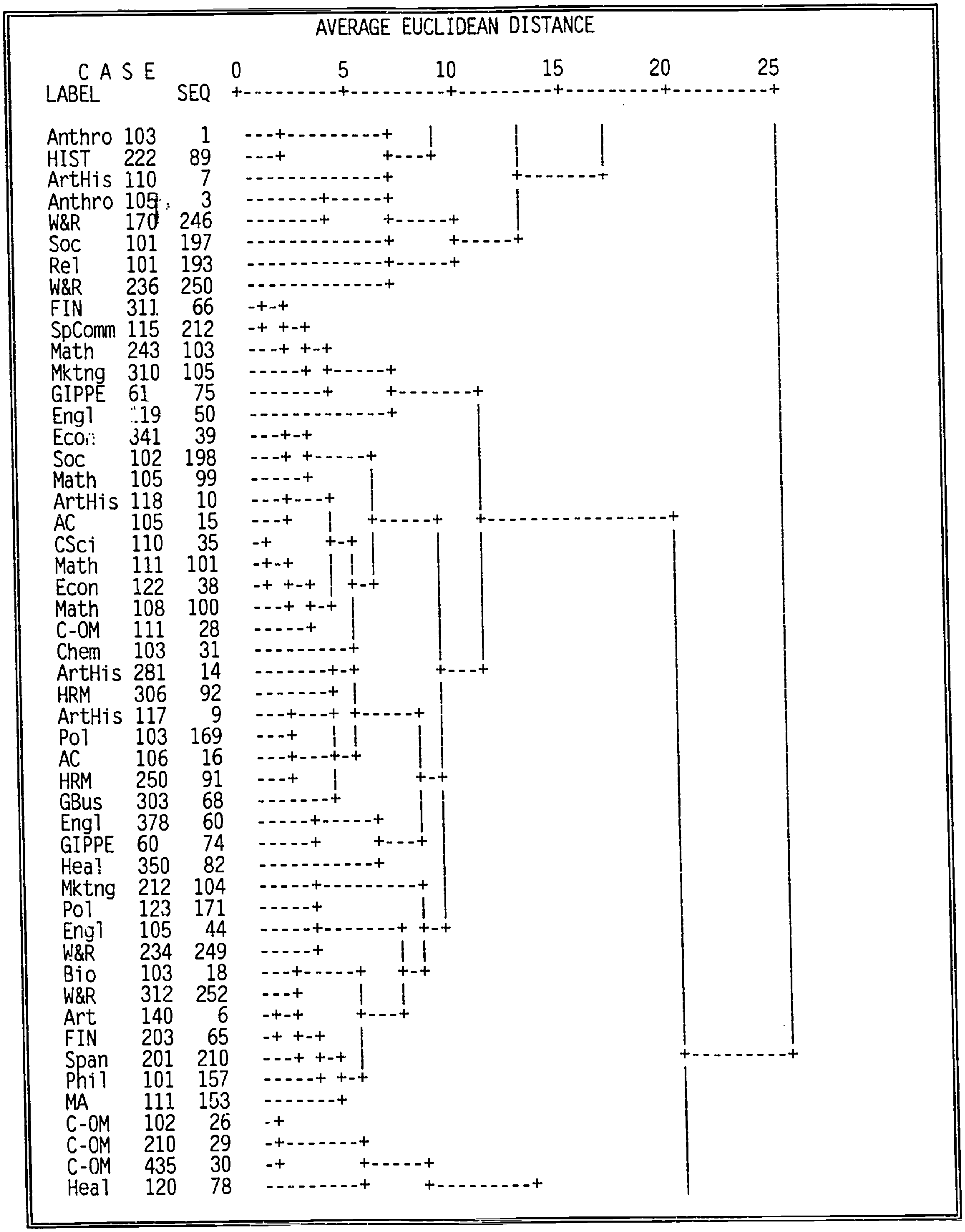


Figure 9. SPSS-X Dendrogram - High Verbal/Low Math Ability Grouping (continued).

```
                          AVERAGE EUCLIDEAN DISTANCE

 C A S E          0         5        10        15        20        25
LABEL         SEQ +---------+---------+---------+---------+---------+

Math     155  102  ---+-----+     |         |             |
Soc      207  203  ---+     +-----+         |             |
PhysEd   92   165  ---------+               |             |
LibRes   105   95  -+-----+                 |             |
Psy      100  175  -+     |                 |             |
Heal     202   79  ---+-+ +-------+         |             |
PhysTh   103  166  ---+ +-+       |         +-----+       |
Econ     121   37  ---+-+ |       |         |     |       |
HRM      340   93  ---+   |       |         |     |       |
Psy      101  176  -------+       +-----+   |     |       |
GIPPE    29    71  ---+---+       |     |   |     |       |
Soc      205  202  ---+   +---+   |     |   |     |       |
PhysEd   125  162  -+-+   |   |   |     |   |     |       |
PhysEd   126  163  -+ +---+   |   |     |   |     |       |
W&R      108  245  ---+       +---+     +---+     |       |
Thea     100  223  -----+-+   |         |         |       |
Thea     131  224  -----+ +-+ |         |         |       |
MA       220  154  -------+ +-+         |         |       |
TV-R     241  235  ---------+           |         +-------+
Span     101  208  ---------------------+         |
Art      130    5  -------+-----+                 |
Pol      122  170  -------+     +-------+         |
Heal     219   80  -------------+       +-------+ |
ArtHis   230   13  -------+-------+     |       | |
Soc      323  207  -------+       +-----+       | |
Educ     200   40  ---+---------+ |             | |
TV-R     330  240  ---+         +-+             | |
Bio      104   19  ---+-----+   |               | |
Math     101   98  ---+     +---+               | |
HIST     111   87  ---+---+ |                   | |
HIST     112   88  ---+   +-+                   +-+
GBus     304   69  -----+-+                     |
MA       421  155  -----+                       |
GIPPE    16    70  -----------+---+             |
Mu:Ed    125  129  -----------+   +---------+   |
EIL      118   62  -----------+---+         |   |
GIPPE    38    73  -----------+             |   |
GIPPE    73    76  -+-+                     |   |
Heal     228   81  -+ +-----+               +---+
CP       242   34  ---+     +---------+     |
Bio      121   23  -+-----+ |         |     |
Bio      122   24  -+     +-+         |     |
Psy      341  192  -------+           |     |
```

Figure 9. SPSS-X Dendrogram - High Verbal/Low Math Ability Grouping (continued).

```
                          AVERAGE EUCLIDEAN DISTANCE

   C A S E           0         5        10        15        20        25
 LABEL         SEQ   +---------+---------+---------+---------+---------+

 CSci    157    36    -------+---+       +-----+
 W&R     238   251    -------+   +---+   |
 Heal    113    77    -----+-+   |   |   |
 Soc     104   199    -----+ +---+   |   |
 Rel     104   194    -------+       +---+
 Pol     328   173    ---+---+       |
 Soc     215   206    ---+   +---+   |
 CP      241    33    -------+   |   |
 GIPPE    34    72    -------+   +---+
 Mu:Ed   145   135    -----+-+   |
 PhysEd  295   164    -----+ +---+
 C-OM    108    27    -------+
```

Figure 10. Dendrogram Summary: 9-cluster solution
High/Low Group

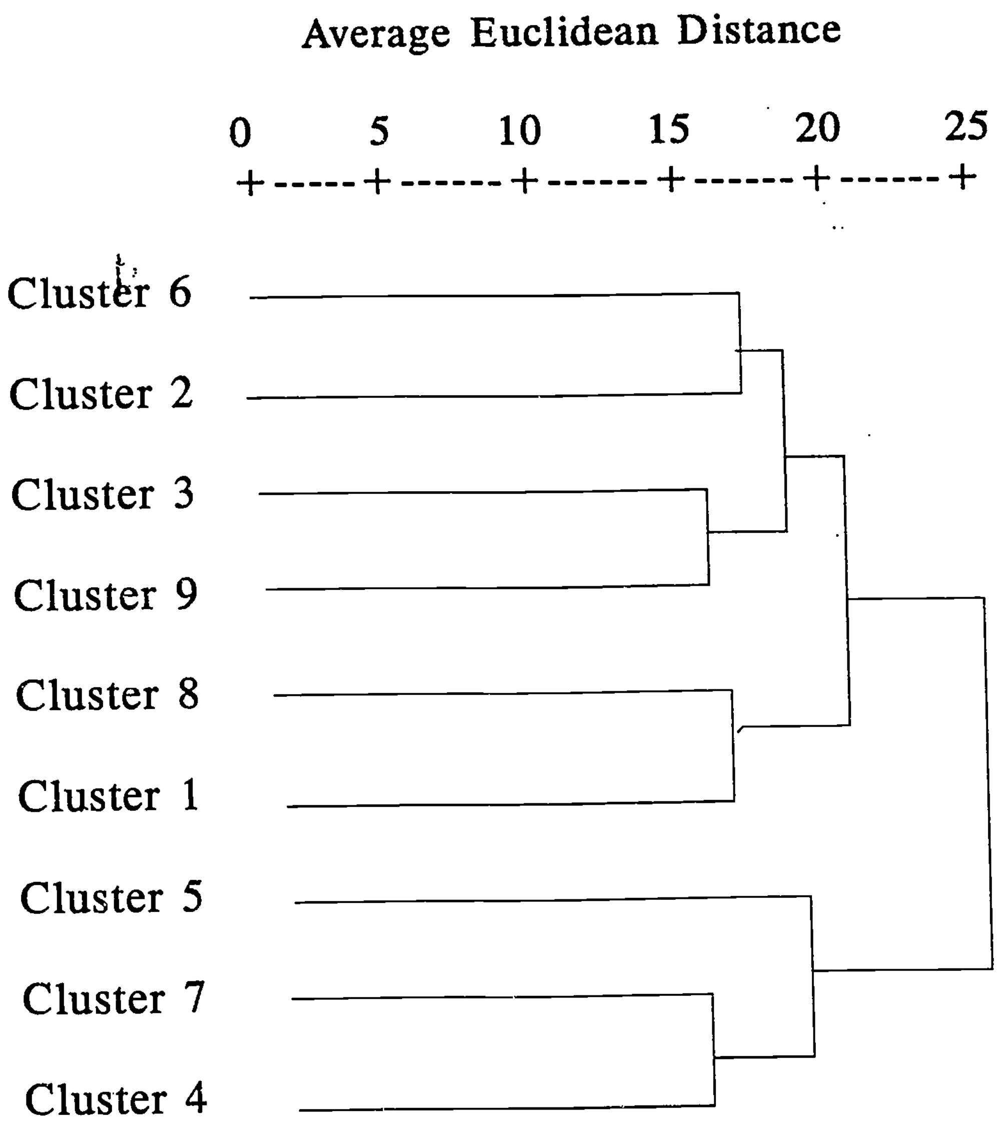


Figure 11. Courses Within Coursework Clusters: 9-cluster solution Eastern College Combined Sample - High/Low Group.

Cluster 1 (n = 10)	Cluster 2 (n = 76)	Cluster 2 (continued)	Cluster 3 (n = 29)
Anthro 103	Anthro 104	Mu:Ed 133	Anthro 107
Anthro 105	ArtHis 112	Mu:Ed 134	ArtHis 218
ArtHis 110 *	Bio 112	Mu:Ed 163	ArtHis 220
HIST 222	C-OM 101 *	Mu:Ed 166	Bio 110 *
HIST 362	CP 101	Mu:Ed 231	Bio 115
Math 100 *	Educ 340	Mu:Ed 232	Educ 219
Rel 101 *	Engl 109	Mu:Ed 233	Fren 201
Soc 101	Engl 110	Mu:Ed 234	Germ 101
W&R 170	Engl 112 *	Mu:Ed 255	HIST 101
W&R 236	Engl 113	Mu:Ed 256	MRA 102
	Engl 131	Mu:Ed 303	Mu:AM 101
	Engl 214	Mu:Ed 304	Mu:AM 102
	Engl 219	Mu:Ed 331	Mu:AM 401
	Engl 232	Mu:Ed 332	Mu:AS 155
	Engl 271	Mu:Ed 355	Mu:AS 156
	Engl 272	Mu:Ed 367	Mu:Ed 108
	Engl 312	Mu:Ed 368	Mu:Ed 113
	Engl 363	Mu:Ed 471	Mu:NM 101
	Engl 377	Phys 170	Phil 102
	Engl 381	Pol 102	PhysEd 105
	Heal 450	Pol 142 *	Psy 210
	HIST 105	Rel 207	Psy 311 *
	IISt 101	Russ 101 *	Psy 321
	Mu:AM 201	Soc 202	Soc 203
	Mu:AM 202	Soc 210	SPath 100
	Mu:AM 301	Soc 214	Thea 140
	Mu:AS 101	Span 102	Thea 160
	Mu:AS 103	SpComm 140	Thea 363
	Mu:AS 104	SpComm 150	W&R 201
	Mu:AS 127	SpComm 230	
	Mu:AS 129	SpComm 353	
	Mu:AS 141	TV-R 121	
	Mu:AS 251	TV-R 202	
	Mu:AS 258	TV-R 297 *	
	Mu:Ed 106	W&R 107 *	
	Mu:Ed 107		
	Mu:Ed 109		
	Mu:Ed 110		
	Mu:Ed 111		
	Mu:Ed 131		
	Mu:Ed 132		

Figure 11. Courses Within Coursework Clusters: 9-cluster solution
Eastern College Combined Sample - High/Low Group (continued).

Cluster 4
(n = 35)

Art	130	
ArtHis	230	
Bio	104	
Bio	121	
Bio	122	
C-OM	108	
CP	241	
CP	242	
CSci	157	
Educ	200	
EIL	118	
GBus	304	
GIPPE	16	
GIPPE	34	
GIPPE	38	
GIPPE	73	
Heal	113	
Heal	219	
Heal	228	
HIST	111	
HIST	112	
MA	421	
Math	101	
Mu:Ed	125	
Mu:Ed	145	
PhysEd	295	
Pol	122	*
Pol	328	
Psy	341	
Rel	104	
Soc	104	
Soc	215	
Soc	323	
TV-R	330	
W&R	238	

Cluster 5
(n = 38)

AC	105	
AC	106	
Art	140	
ArtHis	117	
ArtHis	118	
ArtHis	281	
Bio	103	
C-OM	111	*
Chem	103	
CSci	110	
Econ	122	*
Econ	341	
Engl	105	*
Engl	119	*
Engl	378	
FIN	203	
FIN	311	
GBus	303	
GIPPE	60	
GIPPE	61	
Heal	350	
HRM	250	
HRM	306	
MA	111	
Math	105	
Math	108	
Math	111	
Math	243	
Mktng	212	
Mktng	310	
Phil	101	
Pol	103	
Pol	123	
Soc	102	
Span	201	
SpComm	115	
W&R	234	*
W&R	312	

Cluster 6
(n = 25)

AHS	101	
Educ	299	
Engl	107	
Fren	101	
HIST	102	
Pol	101	
Pol	342	
Psy	102	
Psy	121	
Psy	241	
SpComm	110	
SpComm	149	
SpComm	327	*
SpComm	428	*
TV-R	101	
TV-R	102	
TV-R	131	
TV-R	196	
TV-R	232	
TV-R	296	
TV-R	312	
TV-R	322	
TV-R	498	
W&R	104	*
W&R	205	

Cluster 7
(n = 24)

C-OM	102	
C-OM	210	
C-OM	435	
Econ	121	
GIPPE	29	
Heal	120	
Heal	202	
HRM	340	
LibRes	105	
MA	220	
Math	155	

Cluster 7
(continued)

PhysEd	125	
PhysEd	126	
PhysEd	92	*
PhysTh	103	
Psy	100	
Psy	101	
Soc	205	
Soc	207	
Span	101	
Thea	100	
Thea	131	
TV-R	241	
W&R	108	

Cluster 8
(n = 14)

Ling	233
Mu:Ed	130
Phys	160
Psy	201
Psy	208
Psy	209
Psy	302
Psy	303
Psy	308
Psy	309
Psy	316
SPath	202
SPath	203
W&R	106

Cluster 9
(n = 1)

Psy	202

Figure 12. Discriminant Analysis of the 9-Cluster Solution for the Eastern College Combined Sample - High/Low Group.

Actual Group	No. of Cases	PREDICTED GROUP MEMBERSHIP 1	2	3	4	5	6	7	8	9
Group 1	10	**7** **70.0%**	0 0.0%	0 0.0%	1 10.0%	0 0.0%	2 20.0%	0 0.0%	0 0.0%	0 0.0%
Group 2	76	0 0.0%	**70** **92.1%**	0 0.0%	0 0.0%	3 3.9%	3 3.9%	0 0.0%	0 0.0%	0 0.0%
Group 3	29	0 0.0%	0 0.0%	**27** **93.1%**	0 0.0%	0 0.0%	0 0.0%	0 0.0%	2 6.9%	0 0.0%
Group 4	35	0 0.0%	0 0.0%	0 0.0%	**34** **97.1%**	0 0.0%	1 2.9%	0 0.0%	0 0.0%	0 0.0%
Group 5	38	0 0.0%	2 5.3%	0 0.0%	0 0.0%	**33** **86.8%**	0 0.0%	3 7.9%	0 0.0%	0 0.0%
Group 6	25	0 0.0%	2 8.0%	0 0.0%	1 4.0%	0 0.0%	**22** **88.0%**	0 0.0%	0 0.0%	0 0.0%
Group 7	24	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 4.2%	0 0.0%	**23** **95.8%**	0 0.0%	0 0.0%
Group 8	14	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	**14** **100.0%**	0 0.0%
Group 9	1	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	**1** **100.0%**

Percent of "Grouped" Cases Correctly Classified: 91.67%

Figure 13. Correlations Between Rotated Canonical Discriminant Functions and Discriminating Variables - High/Low Group.

Mean Residual Item-type	Func 1	Func 2	Func 3	Func 4	Func 5	Func 6	Func 7	Func 8
Analogy	0.03765	0.07795	0.11906	0.00636	0.14503	0.03321	**0.92580**	-0.23457
Antonyms	-0.02706	0.22856	-0.20100	-0.01468	0.05580	-0.09558	-0.08189	-0.46555
Sentence Completion	0.07444	0.09831	-0.08562	-0.01791	-0.00283	**0.91544**	0.17297	0.00073
Reading Comprehension	0.04798	0.12443	0.03289	**0.94311**	-0.24672	-0.03208	-0.00782	0.04627
Quantitative Comparisons	0.04122	0.24254	**0.80299**	0.01308	0.14036	-0.08014	0.05501	-0.12582
Regular Math	0.0[illegible]268	**0.97213**	0.10962	0.03838	0.17053	-0.01160	0.00340	0.08841
Data Interpretation	0.09715	0.12718	0.00197	-0.06399	**0.94851**	-0.03885	0.03049	0.18109
Analytic Reasoning	**0.89321**	0.12836	0.01762	0.02015	0.27762	-0.01220	-0.00425	0.13013
Logical Reasoning	0.02456	0.18697	0.14578	-0.00034	0.18727	-0.06922	-0.21691	**0.77738**

Correlations of coursework clusters and discriminant functions: High/Low Group

Figure 13 summarizes relationships between GRE item-type residuals and the rotated canonical discriminant functions:

Function 1 was positively correlated to Analytic Reasoning (r=.89);
Function 2 was positively correlated to Regular Mathematics (r=.97);
Function 3 was positively correlated to Quantitative Comparisons (r=.80);
Function 4 was positively correlated to Reading Comprehension (r=.94);
Function 5 was positively correlated to Data Interpretation (r=.95);
Function 6 was positively correlated to Sentence Completion (r=.92);
Function 7 was positively correlated to Analogies (r=.93);
Function 8 was positively correlated to Logical Reasoning (r=.78);

The rotated correlations establish relationships between the discriminant functions and the GRE item-type residuals. Each discriminant function explains a certain proportion of the variation in residual scores. In this case, each discriminant function was strongly and positively related to a specific GRE item-type residual.

Discriminant functions with strong explanatory power, "good discriminant functions," have large between-cluster variability and low within-cluster variability (Norusis, 1985). The eigenvalues of Figure 14 present the ratio of between-group to within-group sums of squares of the residuals. Large eigenvalues are associated with the discriminant functions that most contribute to explaining variability in GRE item-type scores. Functions 1, 2, 3, and 4 had eigenvalues indicating that their each accounted for 6 or more percent of the variance. Collectively, these four functions accounted for over 93 percent of the variance in residuals.

Wilk's Lambda is the ratio of the within-group sum of squares to the total sum of the squares. It represents the proportion of the total variance in the discriminant function values not explained by differences among cluster groups. Wilk's Lambda serves as a test of the null hypothesis that there is no difference in the mean residuals of a coursework cluster means and the mean residual scores of the coursework in the total sample. Lambda scores affirmed the hypotheses that difference coursework clusters were associated with different types of learning gains. Once again, the data confirmed the differential coursework patterns hypothesis: that different enrollment patterns were associated with different gains in student learning. Thus, the eigenvalues and canonical correlations indicated the extent to which each discriminant function contributes to our understanding of the variability in coursework mean residuals. Lambda tested the null of the differential coursework hypothesis for each discriminant function.

Figure 14. Canonical Discriminant Functions: Eastern College Combined Sample - High/Low Group.

Function	Eigen value	Percent of Variance	Cum. Percent	Canonical Correlation	Wilks' Lambda	D.F.	Significance
					0.0300	72	0.0000
1*	2.9167	48.20	48.20	0.8629	0.1175	56	0.0000
2*	1.7157	28.36	76.56	0.7948	0.3191	42	0.0000
3*	0.7680	12.69	89.25	0.6590	0.5642	30	0.0000
4*	0.3823	6.32	95.57	0.5259	0.7799	20	0.0000
5*	0.2055	3.40	98.97	0.4128	0.9402	12	0.2464
6*	0.0374	0.62	99.59	0.1899	0.9754	6	0.4209
7*	0.0181	0.30	99.89	0.1335	0.9931	2	0.4351
8*	0.0069	0.11	100.0	0.0827			

Rotation of the functions enhances the interpretability of the results. After rotation, Functions 1 through 6 each accounted for more than five percent of the variance in residuals totaling 93.7%. Functions 5, 6, 7 and 8 accounted for less than 5 percent of the variance. Functions 1 through 6 were used in the further analysis of the coursework clusters.

Once the relationships between discriminant functions and mean item-type residuals were established and the strength of the discriminant functions is known, then the relationships between the discriminant functions and the coursework clusters were also determined. By examining the average score of each cluster group for each discriminant function, the extent to which each discriminant function contributes to that group was calculated. The average residual score for a coursework cluster group is called the group centroid. Group centroids for each coursework cluster in the High/Low Group are presented in Figure 15.

Figure 15. Canonical Discriminant Functions Evaluated at Group Means (Group Centroids) - High/Low Group.

Cluster	Func 1	Func 2	Func 3	Func 4	Func 5	Func 6	Func 7	Func 8
1	0.46582	-1.85057	-0.27686	-0.84334	1.61849	0.20039	-0.36354	-0.72670
2	1.45215	-0.51483	-0.87415	0.45257	-0.74485	-0.54717	0.38835	0.13664
3	-0.81143	-0.66787	0.76922	1.41847	-0.70342	-0.50962	0.43354	0.00741
4	-1.93768	0.41975	-0.63880	-1.10006	0.51957	0.46800	-0.01852	-0.39576
5	0.82742	2.09262	1.59168	-0.74170	0.32789	1.06449	-0.56352	-0.13946
6	-0.84300	-1.59056	-1.16842	0.29575	0.33407	-0.09151	0.26418	-0.04341
7	-1.41007	0.94519	1.51685	-0.41555	0.05645	0.34169	-0.64396	-0.18115
8	0.05168	0.05218	0.06456	0.19884	1.47268	-0.53275	-0.62763	1.41986
9	-0.92023	-0.86086	0.67287	-0.61517	-0.14580	-0.92509	1.24739	1.37373

<u>Interpreting the coursework clusters for the 9-cluster solution: High/Low Group</u>

Figure 15 shows the coursework cluster means (group centroids) for each discriminant function having significant correlations with specific item-types whose residuals fit the general linear model. Coursework clusters with positive or negative means greater than 1.0 were selected for further analysis.

Coursework Cluster #1 had a high negative mean on Function 2 and a high positive mean on Function 5. Function 2 is positively correlated with Regular Mathematics and Function 5 is positively correlated with Data Interpretation. Students in this group of courses showed less than expected performance in Regular Mathematics but gained in Data Interpretation.

Cluster #2 had a high positive mean on Function 1. Function 1 was positively correlated to Analytic Reasoning. Students enrolling in this cluster gained in Analytic Reasoning skills.

Cluster #3 showed a high positive group mean on Function 4. Function 4 was positively correlated with Reading Comprehension. Students taking this coursework pattern experienced gains in Reading Comprehension.

Cluster #4 showed high negative means on Functions 1 and 4. Function 1 was positively correlated with Analytic Reasoning and Function 4 was positively correlated with Reading Comprehension. Students enrolled in this cluster declined in Analytic Reasoning and Reading Comprehension.

Cluster #5 had high positive group means on Functions 2, 3, and 6. Functions 2 and 3 were positively correlated with Regular Mathematics and Quantitative Comparisons, respectively. Function 6 was positively associated with Sentence Completions. Those enrolled in this coursework pattern showed gains in Regular Mathematics, Quantitative Comparisons, and Sentence Completions item-types.

Cluster #6 displayed high negative means on Functions 2 and 3. Function 2 was positively correlated with Regular Mathematics while Function 3 was positively correlated with Quantitative Comparisons. Students receiving instruction in these courses declined in Regular Mathematics and Quantitative Comparisons item-types.

Cluster #7 had a high negative group mean on Function 1 and a high positive group mean on Function 3. Functions 1 and 3 were positively correlated with Analytic Reasoning and Quantitative Comparisons. Participants enrolled in these courses declined in Analytic Reasoning but gained in Quantitative Comparisons.

Cluster #8 had a high positive mean on Function 5. Student enrolling in this cluster showed gains in Data Interpretation.

Cluster #9 did not show any high positive or negative means on any of the six functions. No conclusions can be drawn about this cluster on the basis of this analysis.

Results

This study began with an analysis of the learning gains of students entering Eastern College with high verbal and low mathematics skills as measured by SAT scores. Score residuals showed that this Group showed gains in learning along each of the 9 GRE item-type dimensions assessed (Figure 5). The coursework in which these students enrolled was grouped according to course means of student residual scores, and certain course clusters were found to be associated with specific types of learning.

Cluster #5 students made significant gains in two areas where their precollege scores suggested they were weak, Regular Math and Quantitative Comparisons. Students enrolling in Cluster #6 coursework continued to underperform in areas where they were weak upon admission to Eastern, Regular Mathematics and Quantitative Comparisons. Finally, Cluster #7 enrollees declined in Analytic Reasoning but improved in Quantitative Comparisons. Taking different patterns of coursework clearly was associated with different learning results, both positively and negatively.

Figure 16 portrays the coursework clusters and the mean residual item-types with which they were found to be associated. It should be cautioned that the association was established at the <u>cluster</u> level. No direct causal link is intimated between student enrollment in any one given course and scores on the GRE.

Figure 16. Courses Within Coursework Clusters for Eastern College Combined Sample Subgroup - High/Low Group.

Cluster 1: High negative mean residuals on Regular Mathematics (RM).
High positive mean residuals on Data Interpretation (DI).

	Anthro	103	Biological Anthropology
	Anthro	105	Introduction to Archeology
*	ArtHis	110	Introduction to Art
	Hist	222	History of the USSR
	Hist	362	Modern European Intellectual History
*	Math	100	Mathematics-Fundamentals
*	Rel	101	Introduction to Religion
	Soc	101	Introduction to Sociology
	W&R	170	Personal Essay
	W&R	236	Elements of the Short Story

Cluster 2: High positive mean residuals on Analytic Reasoning (AR).

	Anthro	104	Cultural Anthropology
	ArtHis	112	Introduction to Architecture
	Bio	112	Food, Health and Federal Control
*	C-OM	101	Theories of Communications Media
	CP	101	Introduction to Film Aesthetics and Analysis
	Educ	340	Foundations of Education
	Engl	109	Introduction to Drama
	Engl	110	Introduction to Fiction
*	Engl	112	Introduction to Short Story
	Engl	113	Introduction to Poetry
	Engl	131	Ancient Literature
	Engl	214	Science Fiction
	Engl	219	Shakespeare
	Engl	232	Medieval Literature
	Engl	271	Renaissance Literature
	Engl	272	Literature, 1660-1770: The Enlightenment
	Engl	312	Dramatic Literature
	Engl	363	Irish Literature
	Engl	377	Nineteenth Century British Novel
	Engl	381	Romantic-Victorian Literature
	Heal	450	Psychoactive Drugs: Independent Study
	Hist	105	News of the Day
	IISt	101	[No title available.]
	Mu:AM	201	Voice: Second Year
	Mu:AM	202	Voice: Second Year

Figure 16. Courses Within Coursework Clusters for Eastern College Combined Sample Subgroup - High/Low Group (continued)

Cluster 2 (continued)

	Mu:AM	301	Voice: Third Year
	Mu:AS	101	Voice
	Mu:AS	103	Piano
	Mu:AS	104	Piano
	Mu:AS	127	Bassoon
	Mu:AS	129	Saxophone
	Mu:AS	141	Percussion
	Mu:AS	251	[No title available.]
	Mu:AS	258	Italian Diction
	Mu:Ed	106	Concert Band
	Mu:Ed	107	Symphonic Band
	Mu:Ed	109	Chorus
	Mu:Ed	110	Women's Chorale
	Mu:Ed	111	Orchestra
	Mu:Ed	131	Music Theory I
	Mu:Ed	132	Music Theory II
	Mu:Ed	133	Sightsinging and Movement
	Mu:Ed	134	Sightsinging and Movement
	Mu:Ed	163	Music in London
	Mu:Ed	166	Career Orientation
	Mu:Ed	231	Music Theory III
	Mu:Ed	232	Music Theory IV
	Mu:Ed	233	Sightsinging-Advanced
	Mu:Ed	234	Sightsinging-Advanced
	Mu:Ed	255	History and Literature of Music
	Mu:Ed	256	History and Literature of Music
	Mu:Ed	303	Instrumental Conducting
	Mu:Ed	304	Instrumental Conducting
	Mu:Ed	331	Techniques of 20th Century Composition
	Mu:Ed	332	Form and Analysis
	Mu:Ed	355	Music in the Twentieth Century
	Mu:Ed	367	Music in Elementary School
	Mu:Ed	368	General and Choral Music in the Secondary School
	Mu:Ed	471	Introduction to Woodwind Repair
	Phys	170	Descriptive Astronomy
	Pol	102	Media and Politics
*	Pol	142	Ideas and Ideologies
	Rel	207	Death and Immortality
*	Russ	101	Elementary Russian
	Soc	202	Contemporary Social Issues-Women in Britain
	Soc	210	Women's Lives

Figure 16. Courses Within Coursework Clusters for Eastern College Combined Sample Subgroup - High/Low Group (continued)

Cluster 2 (continued)

	Soc	214	Definitions of Normality
	Span	102	Elementary Spanish
	SpComm	140	Small Group Communication
	SpComm	150	Introduction to Communication Theory
	SpComm	230	Oral Interpretation of Literature
	SpComm	353	General Semantics
	TV-R	121	Introduction to Mass Media
	TV-R	202	Television Directing
*	TV-R	297	Research and Program Planning
*	W&R	107	Academic Writing II

Cluster 3: High positive mean residuals on Reading Comprehension (RD).

	Anthro	107	The World Before History
	ArtHis	218	British Art and Architecture II: 1660-1914
	ArtHis	220	Medieval Art and Architecture
*	Bio	110	Behavior in Animals
	Bio	115	Essentials of Biology
	Educ	219	Elements of Tutoring
	Fren	201	Intermediate French
	Germ	101	Elementary German I
	Hist	101	Development of Western Civilization I
	MRA	102	Medical Terminology
	Mu:AM	101	Flute:First Year
	Mu:AM	102	Flute:First Year
	Mu:AM	401	Voice: Fourth Year
	Mu:AS	155	German Diction
	Mu:AS	156	French Diction
	Mu:Ed	108	Choir
	Mu:Ed	113	Madrigal Singers
	MU:NM	101	Music Lessons for Non-majors
	Phil	102	Introduction to Philosophy: Greek Foundations
	PhysEd	105	Leadership
	Psy	210	Educational Psychology
*	Psy	311	Physiological Psychology
	Psy	321	Abnormal Psychology
	Soc	203	Juvenile Delinquency
	SPath	100	Sign Language I
	Thea	140	Rehearsal and Performance
	Thea	160	Introduction to the Theatre
	Thea	363	Drama and the London Theatre
	W&R	201	Persuasive Argument

Figure 16. Courses Within Coursework Clusters (9-cluster solution)
Eastern Combined Sample - High/Low Group (continued)

Cluster 4: High negative mean residuals on Analytic Reasoning (AR) and Reading Comprehension (RD).

	Art	130	Introduction to Drawing
	ArtHis	230	Renaissance Art
	Bio	104	Environmental Biology
	Bio	121	Principles of Biology
	Bio	122	Principles of Biology
	C-OM	108	Human Communication in Organizations
	CP	241	Introduction to Photography
	CP	242	Intermediate Photography
	CSci	157	Ex Machina: The Computer and You
	Educ	200	Introduction to Education
	EIL	118	[No title available.]
	GBus	304	Business Law II
	GIPPE	16	Basic Tennis
	GIPPE	34	Personal Defense
	GIPPE	38	Beginning Jazz
	GIPPE	73	Personal Fitness I
	Heal	113	Personal Health
	Heal	219	Principles of Accident Prevention
	Heal	228	Human Sexuality
	Hist	111	American History to
	Hist	112	American History Since 1865
	MA	421	Business Policy
	Math	101	Pre-Calculus/Algebraic Skills
	Mu:Ed	125	Vocal Jazz Ensemble
	Mu:Ed	145	Introduction to Electronic Music
	PhysEd	295	Social Aspects of Sport
*	Pol	122	Politics and Society
	Pol	328	International Conflict
	Psy	341	Family Therapy
	Rel	104	Introduction to the Bible (New Testament)
	Soc	104	Research Methods
	Soc	215	Intro to Contemporary Mental Health Issues
	Soc	323	Family Violence
	TV-R	330	Advertising Copywriting and Visualization
	W&R	238	Poetry Writing

Figure 16. Courses Within Coursework Clusters (9-cluster solution)
Eastern Combined Sample - High/Low Group (continued)

Cluster 5: High positive mean residuals on Regular Mathematics (RM), Quantitative Comparisons (QC) and Sentence Completion (SC).

	AC	105	Principles of Accounting I
	AC	106	Principles of Accounting II
	Art	140	Introduction to Painting
	ArtHis	117	Survey of Western Art
	ArtHis	118	Survey of Western Art
	ArtHis	281	American Art and Architecture to 1913
	Bio	103	[No title available.]
*	C-OM	111	Design & Production of Instructional Materials
	Chem	103	Origins of Life
	CSci	110	Introduction to Data Processing
*	Econ	122	Principles of Micro Economics
	Econ	341	Microanalysis
*	Engl	105	Intro to Literature: Masterpieces of Western Lit.
*	Engl	119	[No title available.]
	Engl	378	20th Century British Novel
	FIN	203	Principles of Banking and Finance
	FIN	311	Business Finance
	GBus	303	Business Law I
	GIPPE	60	Bowling
	GIPPE	61	Bowling II
	Heal	350	Psychoactive Drugs
	HRM	250	Labor Relations
	HRM	306	Organizational Behavior
	MA	111	Introduction to Business
	Math	105	Mathematics for Decision Making
	Math	108	Calculus for Decision Making
	Math	111	Calculus I
	Math	243	Statistics
	Mktng	212	Principles of Marketing
	Mktng	310	Quantitative Methods in Business
	Phil	101	Introduction to Philosophy: Problems
	Pol	103	U.S. and the World
	Pol	123	Political Justice
	Soc	102	Contemporary Sociological Issues
	Span	201	Intermediate Spanish I
	SpComm	115	Business and Professional Communication
*	W&R	234	Humorous Writing
	W&R	312	Professional Writing

Figure 16. Courses Within Coursework Clusters (9-cluster solution)
Eastern Combined Sample - High/Low Group (continued)

Cluster 6: High negative mean residuals on Regular Mathematics (RM) and Quantitative Comparisons (QC).

	AHS	101	Introduction to Gerontology
	Educ	299	Residential Experience: Individuals in Groups
	Engl	107	Intro to Literature: Readings in Major Themes
	Fren	101	Elementary French
	Hist	102	Development of Western Civilization II
	Pol	101	U.S. Politics
	Pol	342	Liberalism and Marxism
	Psy	102	General Psychology: Motivation
	Psy	121	General-Experimental Psychology I
	Psy	241	Psychological Aspects of the Family
	SpComm	110	Public Communication
	SpComm	149	Fundamentals of Interpersonal Communications
*	SpComm	327	Modern and Contemporary Theories of Rhetoric
*	SpComm	428	Research:Rhetorical/Critical Methods
	TV-R	101	Introduction to Broadcast Production
	TV-R	102	Television Production and Direction
	TV-R	131	Media Writing
	TV-R	196	Mass Media Research Methods
	TV-R	232	Public Relations
	TV-R	296	Audience Research
	TV-R	312	Broadcast Regulation
	TV-R	322	New Telecommunication Technologies
	TV-R	498	London Communications Internship
*	W&R	104	Personal Essay
	W&R	205	Personal Essay

Cluster 7: High negative mean residuals on Analytic Reasoning (AR). High positive mean residuals on Quantitative Comparisons (QC).

C-OM	102	Career Development
C-OM	210	Instructional Design Systems
C-OM	435	Corporate Communication Research and Evaluation
Econ	121	Principles of Macro Economics
GIPPE	29	Indoor Tennis
Heal	120	First Aid
Heal	202	Human Nutrition
HRM	340	Personnel Administration
LibRes	105	Library Resources & Methods of Research

Figure 16. Courses Within Coursework Clusters (9-cluster solution)
Eastern Combined Sample - High/Low Group (continued)

Cluster 7 (continued)

	MA	220	Management Theory Principles of Management
	Math	155	Basic Statistical Reasoning
	PhysEd	125	Human Anatomy
	PhysEd	126	Human Anatomy Lab
*	PhysEd	92	Crew-Men-Intercollegiate Athletics
	PhysTh	103	Introduction to Health Professions
	Psy	100	The Psychology of Adjustment
	Psy	101	General Psychology: Development
	Soc	205	Sociology of Responsibility
	Soc	207	Race and Ethnicity
	Span	101	Elementary Spanish
	Thea	100	Theatre Practice
	Thea	131	Introduction to Acting I
	TV-R	241	Advertising
	W&R	108	Foundations of Writing

Cluster 8: High positive mean residuals on Data Interpretation (DI).

Ling	233	Introduction to Linguistics
Mu:Ed	130	Music Society
Phys	160	Physics of Sound
Psy	201	Proseminar in Development
Psy	208	Descriptive Statistics
Psy	209	Computer-Based Inferential Statistics
Psy	302	Research Team Participation
Psy	303	Research Team Participation
Psy	308	Methodology: Analysis of Design
Psy	309	Methodology-Testing
Psy	316	Social Psychology
SPath	202	Phonetics
SPath	203	Introduction to Speech Correction
W&R	106	Writing From Sources

Cluster 9: No high positive or negative mean residuals.

Psy	202	Proseminar in Motivation

Students enrolling in Cluster #1 coursework underperformed their peers in Regular Mathematics; however these students outperformed their peers on Data Interpretation. It should be noted that only one Math class appears in this Cluster and that is a developmental mathematics course. Students in Cluster #2 showed significant gains in Analytic Reasoning; like the total combined sample of 5 graduating classes of Eastern students, those enrolling in this cluster showed marked gains in this ability. Cluster #3 enrollees experienced further gains in verbal abilities, namely Reading Comprehension; they tended to build upon their precollege strengths. Cluster #4 underperformed their peers in one of their areas of strength, Reading Comprehension, and also showed declines in Analytic Reasoning. Aside from the developmental mathematics course in Cluster #1, no mathematics coursework appears in the first four coursework clusters.

The clusters that are perhaps of most interest for the purposes of this analysis are Clusters 5, 7, and 8. These coursework clusters are associated with gains in the three quantitative GRE item-types: Regular Math, Quantitative Comparisons, and Data Interpretation. Students who entered college with high verbal abilities but low math skills who enrolled in these courses showed learning gains in quantitative skills.

Students who enrolled in the courses in Cluster 5 showed gains in Regular Mathematics and Quantitative Comparisons in addition to gains in the verbal item-type of Sentence Completions. Courses in this cluster included Accounting sequence, AC 105 and AC 106, Computer Science 110, Chemistry 103, Economics 341, Finance 203 and 311, Mathematics 105, 108, 111, and 243, and two Marketing courses, including one entitled 'Quantitative Methods in Business.' In addition courses in departments less associated with math skills were represented in the cluster including two 100-level Art History courses, Spanish 201, Political Science 103 and 123, among others.

While students who took the courses represented in Cluster 7 showed less than expected performance in Analytic Reasoning skills, they gained in Quantitative Comparison skills. Courses in this cluster included Communication & Organizational Media courses, CO-M 210 "Instructional Systems Design," CO-M 435 "Corporate Communication Research and Evaluation," Economics 121 "Principles of Macro Economics," two Health courses, an upper-level Human Resources Management course, and two Theater courses. The cluster also included a Math course on Basic Statistical Reasoning, two psychology courses and two sociology courses. Because these coursework patterns included enrollment patterns from 5 successive graduating classes of Eastern College seniors, course associations were consistent over that period.

Cluster 8 was associated with gains in Data Interpretation. The majority of courses in this cluster in Psychology. Eight of the 14 courses in this cluster were 200- and 300-level psychology courses, many of which emphasized statistics and research methodology. One physics class, two speech pathology courses, and one course each from the linguistics, music, and writing & reading departments rounded out the cluster.

Students enrolling in coursework Cluster #6 underperformed their peers in terms of learning gains in Regular Mathematics and Quantitative Comparisons. No mathematics, science or applied science coursework appeared in this cluster. It suggests that these students avoided contact with math related subjects while completing their degree in a manner that did not allow them to demonstrate gains in any other area measured by the GRE.

While some of these courses appeared to be similar to the total combined sample in their associations with the development of quantitative skills (Ratcliff, Yaeger & Hoffman, 1994), many of the courses in this High/Low Group were associated with significantly different outcomes than the total sample. For example, several of the courses in Cluster 5 were not associated with quantitative improvements in the total sample. The chemistry, computer science, political science and sociology courses were not associated with gains in quantitative skills in the total sample.

Furthermore, at this point, one cannot say why students who enrolled in these courses had higher residuals. The cluster serves to hypothesize relationships between coursework patterns and the general learned abilities measures by the item-types of the GRE. One can say that students who enrolled in specific patterns of coursework tended to evidence stronger gains on specific item-types within the GRE, while others who enrolled in different coursework patterns did not tend to show such gains. This evidence affirms the hypothesis that student gains in general learned abilities are associated, positively and negatively, with the coursework in which they enrolled. Further analysis is required to determine the nature of these associations.

Conclusion

The main purpose of this project was to determine if enrollment in different patterns of coursework were associated with gains in the general learned abilities of undergraduate students. The answer to this question was consistently "yes." Taking different patterns of coursework does lead to different types and levels of development as measured by the nine item-types of the GRE General Test.

Several consistent findings emerged from the analysis of coursework clusters. First, the development of general learned abilities did not have an exact one-to-one relationship with departmental categories. All quantitative reasoning development did not occur exclusively in Mathematics classes. Consequently, simple counts of the number of credits or courses a student has taken in a particular subject may not be a reliable proxy of general learning in the attendant subject area. Quantitative skills, for example, may be developed in a variety of subject areas. Second, the development of general learned abilities was not confined to the lower division. This finding was consistent for all samples at Eastern College. General education requirements of colleges should be re-examined in light of student gains in general learned abilities. Coursework that students who showed significant gains took should be examined, evaluated and incorporated into the general education sequence of the college. Third, beyond the college catalog, there was little formal monitoring and description of the curriculum in terms of general learned abilities at the college-wide or university-wide level. Colleges should regularly monitor the number of credits and courses in their curriculum. Without this baseline data, the extent to which students share a common learning experience at a college cannot be readily determined.

The relationships established through the Cluster Analytic Model were associational, not causal. Once a set of courses has been linked to score gains in a specific learned abilities, a targeted investigation can be launched to determine the commonalities of teaching-learning environment, of student and faculty expectations of performance, of the specific abilities of the students who enrolled in the classes. But regardless of what hypotheses are generated about why this coursework is associated with gains in learned abilities, one can state with confidence that students who enrolled in this coursework demonstrated gains on a specific type of learned ability.

One source of variation was between ability groups of students. The coursework associated with gains among high ability students was not the same as that associated with gains among low ability students. Clearly, certain courses were more appropriate for students of lower academic ability, while other courses were associated with gains among higher ability students. This research suggests that while there may not be a perfect course of study for any one student, it is possible to link student assessment and transcript analysis to recommend an array of possible coursework that clearly has been associated with gains in general learned abilities.

At Eastern College as elsewhere, there are students who succeed and learn and those who do not. This research allows the institutional researcher to pinpoint enrollment patterns where students of low math ability further avoid mathematics coursework and mathematics learning (as in Cluster #6). Similarly, it allows the targeting of enrollment patterns for low math/high verbal students who did show gains in quantitative and analytic skills. Armed with this information, the College can provide improved advising, can launch faculty seminar to improve mathematics instruction across disciplines and fields, and can re-examine the effectiveness of the general education requirements in development quantitative skills and abilities.

We know a great deal about what colleges say should be the goals and standards for a baccalaureate degree. This research suggests that much future research is needed to determine what curricular patterns and trends consistently produce the gains in general learning that institutions seek to impart to their students. The challenge of understanding the specific impact of coursework on the learning of students has just begun.

Significance to the Field

Student advising and course selection are based on broad and general stereotypes of what kinds of learning specific courses impart. Faculty advise students who have weak quantitative skills to "take a math course" (Ratcliff, Jones, Guthrie and Oehler, 1991). Core curricula specify single courses that are intended to develop the specific quantitative skills of students. Yet, courses work together cumulatively to build general cognitive skills (Ratcliff, 1992). Rather than attempt to find the one coursework sequence that best fits all students at a given institution, this research provides a means for a college or university to tailor their curriculum to individual students and groups of students who enter college with specific academic strengths and weaknesses. Thus, it points the way for institutions to re-examine their curricula and their use of student assessment data and to make changes which will enhance teaching and learning.

References

Astin, A. (1991). Assessment for Excellence: The Philosophy and Practice of Assessment and Evaluation in Higher Education. New York: American Council on Education, MacMillan Publishing Company.

Jones, E.A. & Ratcliff, J.L. (1991). Which general education curriculum is better: Core curriculum or the distributional requirement? Journal of General Education, 40 (1), 69-101.

Pascarella, E. T., & Terenzini, P. T. (1991). How colleges affects students: Findings and insights from twenty years of research. San Francisco, CA: Jossey-Bass Publishers.

Ratcliff, J.L. (1993). What we can learn from coursework patterns about improving undergraduate curriculum. In J. Ratcliff (ed.), Assessment and Reform of the Undergraduate Curriculum. New Directions for Higher Education. San Francisco: Jossey-Bass, Fall 1993.

Ratcliff, J.L. (1992). Reconceptualizing the college curriculum. Perspectives: The Journal of the Association for General and Liberal Studies, 22 (1), 122-137.

Ratcliff, J.L. (1988). The Effect of Differential Coursework Patterns on General Learned Abilities of College Students: Conceptual Framework, Research Design and Methodology. Report #5. U.S. Dept. of Education, Office of Educational Research and Improvement, Contract No. OERI-R-86-0016, Iowa State Univ., March 1988.

Ratcliff, J.L., Jones, E.A., Guthrie, D.S., and Oehler, D. (1991). The Effect of Coursework Patterns, Advisement, and Course Selection on the Development and of General Learned Abilities of College Graduates: Final Report. University Park, PA: Center for the Study of Higher Education, Penn State University, October 1991. 115p. ERIC Document Reproduction Service No. ED 338 160.

Ratcliff, J.L., Jones, E.A., & Hoffman, S. (1992). Handbook on Linking Assessment and General Education. University Park: National Center on Postsecondary Teaching, Learning and Assessment, Pennsylvania State University. 116p.

Ratcliff, J.L., Yaeger, P.M., & Hoffman, S. (1994). Development and Testing of a Cluster-Analytic Model for Identifying Coursework Patterns Associated with General Learned Abilities of College Students: Report 2 on Ithaca College Combined Sample. University Park, PA: National Center on Postsecondary Teaching, Learning and Assessment; Center for the Study of Higher Education, Pennsylvania State University. 340p.

Romesburg, H.C. (1984). Cluster analysis for researchers. Belmont, CA: Lifelong Learning Publications.

Wilson, K.M. (1985, February). The relationship of GRE general test item-type part scores to undergraduate grades. Princeton, NJ: Educational Testing Service, Report No. ETS-RR-84-38. GREB-81-22P. ERIC Document Reproduction Service ED 255 544.