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AUTHOR ABSTRACT

The purpose of this study was to examine the performance of high school students completing applied mathematics 1 and applied mathematics 2 courses based principally on the CORD Applied Mathematics curriculum in four Missouri school districts. Complete data sets were obtained from 254 students. A general linear model analysis of covariance procedure was used to determine if differences existed in mean scores among students in applied mathematics 1, applied mathematics 2, and a control group of algebra 1 students. Students were tested using the Pre-algebra/algebra portion of the P-ACT+ and the Work Keys Applied Mathematics assessments. Student attitudes toward math as a school subject were also assessed. Students completing applied math 2 were found to make progress comparable to those completing algebra 1. Students enrolled in applied math classes had similar attitudes toward math as algebra students despite having less previous success with math.

INTRODUCTION

Instruction in applied academic courses, including mathematics, has received increased attention as a part of Tech Prep initiatives as well as other efforts to restructure the delivery of education in our schools. The SCANS report (Secretary's Commission on Achieving Necessary Skills, 1991), Tech Prep, Title III of the Perkins Vocational and Applied Technology Education Act (1990) and initiatives related to school to work all suggested the need to restructure education to provide the skills needed to enter the increasingly complex work place. Students must not only understand basic concepts but how to apply them to real world problems (Marshall & Tucker, 1992). Recent work in cognitive psychology has also suggested the need to explore alternate approaches to facilitate student learning (Resnick & Klopfer, 1989).

The Tech Prep initiative has encouraged curriculum reform including the teaching of applied academic courses along lines suggested by Hull and Parnell (1992). One important principle is that students will learn better when courses are taught in a real-world context. Under Title III of the Perkins Act, Tech Prep must, among other things, build student competence in mathematics, science, and communications through a sequential course of study; and lead to employment (Brustein, 1993). In a national study of the evaluation of Tech Prep activities, Custer, Ruhland, & Stewart (1995) found that "a major thrust of Tech Prep has to do with developing and implementing processes for restructuring schools and instituting fundamental changes in the way that education is delivered in America" (p. 14).

Tanner & Chism (1996) reported on a study of applied math student performance in Georgia. They compared the results of students taking applied math 2 and algebra 1 on the SAT-M using scores on the Iowa Test of Basic Skills as a covariant. They found that the students in applied math made significantly higher scores on the SAT-M. The Center for Occupational Research and Development (CORD, 1994) had reported no significant differences in scores of applied math 2 and algebra 1 students on a researcher developed instrument designed to assess algebra skills.

The applied mathematics approach differs from traditional math courses by presenting concepts in the context of real-life events. Abstract ideas are taught in relation to concrete, hands-on activities. Applied course activities are designed to reflect a psychological framework of associative learning and learning style preferences (e.g., Balsam, 1985). Context improves the learning process by allowing relationships to be drawn among associated components.

Several early psychologists emphasized the importance of association in learning (Guthrie, 1935; Hull, 1943; Thorndike, 1931). The structure of these traditional theories consisted of an association between two elements. Current cognitive theory differs from these early educational psychologists by adding a constructivist dimension. For example, Biggs, Hinton & Duncan (1996) state that "learning is a process of knowledge construction rather than knowledge absorption and storage; people use what they already know in constructing new knowledge; and learning is closely related to the context in which it takes place" (p. 35).

In addition to contextual and associative learning theories, the individual learning preference of students is important to their overall cognitive development. Applied mathematics assumes that students learn in differing ways. This idea of differing learning preferences is often called learning styles. Researchers have concluded that people learn in different manners and rates. The idea that individuals comprehend, order, and synthesize concepts in differing manners and rates is the premise of learning styles. Lewis & Steinberger (1991) explain that learning style is the characteristic cognitive, affective, and physiological behaviors that serve as relatively stable indicators of how learners perceive, interact with and respond to their learning environment. Numerous studies have confirmed that the majority of students can accomplish a task if the educational environment matches or compliments their learning style preference (Drummond, 1987; Dunn & Dunn, 1978; Kolb, 1984; Messick, 1984; Pumipuntu, 1992).

An emphasis on context as it relates to facilitating student learning is supported by cognitive theory (e.g., Raizen, 1989; Thomas, 1992; Jones, 1992; Thomas, Johnson, & Anderson, 1992; Resnick & Klopfer, 1989). Resnick & Klopfer suggest that skill and content should be taught at the same time and that students should be provided experiences using real tasks to provide an opportunity for contextualized practice. Cognitive psychology and learning style theories provided a theoretical base for this study. This study was conducted with a foundational assumption that learning is enhanced for many students when teaching methods accommodate active involvement and differing learning preferences.

THE PROBLEM

Many educators believe that students in applied courses learn more and take greater interest in the subject matter. Therefore, there is increased interest in offering more courses taught using an applied approach. However, few studies have examined student performance in applied mathematics courses. The existing research has centered around instructor and student perceptions and concerns related to applied academics (Bristow, 1994; Dennison, 1993; Greene, 1993; Kelly, 1993; Pollard, 1990). With positive reports from teachers, students, and administrators, a study to determine the effect of applied mathematics courses on student performance and perceptions was warranted.

PURPOSE OF STUDY

The purpose of this study was to examine the performance of students enrolled in applied mathematics 1 and applied mathematics 2 courses based principally on the Center for Occupational Research and Development's CORD Applied Mathematics curriculum and methodology.

The specific objectives were:

1. To compare the performance of students in applied math 1, applied math 2, and algebra 1 on the ACT Work Keys competency based math assessment.
2. To compare the performance of students in applied math 1, applied math 2, and algebra 1 on the P-ACT + Pre-Algebra/Algebra assessment.
3. To compare the perceptions of students in applied math and algebra 1 about mathematics as a school subject.

METHODS AND PROCEDURES

This was a quasi-experimental study. It employed a posttest-only control group design to examine the performance of students in applied mathematics and algebra 1 courses on two standardized math assessments. This design was used to avoid pretest/treatment interaction and the regression problem associated with gain scores (Gay, 1992). Students in algebra 1 were used as the control group. Cluster sampling was used with random selection of intact classes by school.

PARTICIPANTS

Four Missouri school districts received a state-funded grant in 1993 to implement an Applied Mathematics curriculum based on the 36 units from CORD (1993) as well as three other applied courses. The districts each offer applied math 1 courses, applied math 2 courses, as well as algebra 1 and other advanced math courses. Schools from these districts were selected to provide data for this study. Twenty-six of 67 randomly selected class sections of applied mathematics and algebra 1 in the four Missouri districts provided data for 490 students. Complete data sets were obtained from a total of 254 subjects. The number of data sets was reduced due to missed tests, data available on the covariant tests, and student attrition and transfers. The data sets included scores on the Work Keys Applied Mathematics test, the Pre-Algebra/Algebra subscore of the Mathematics portion of the P-ACT+, the Math Perception Survey, and a demographic survey. Eighth-grade MMAT Math and Reading scores were also obtained for each subject to serve as covariants.

INSTRUMENTATION

To conduct this study, it was necessary to select appropriate instruments. Thus, the Work Keys Applied Mathematics Assessment was used to assess math taught in context. The P-ACT + Assessment was used to measure traditional math achievement. The Purdue Master Attitude Scale Toward Subject Matter was used to assess student perceptions of math. Finally, a descriptive scale was utilized to derive background data.

WORK KEYS ASSESSMENT

Work Keys is a national system for assessing workplace skills. Among the fourteen different workplace skills assessed in the system, is work-related mathematics. The Work Keys Applied Mathematics assessment is a criterion-referenced instrument that measures an individual's skill in setting up and solving math problems using mathematical reasoning skills generally required in the workplace (American College Testing, 1994). It was designed specifically to measure an individual's preparedness to enter the working world. According to McLarty (1992), "Work Keys assessments embody a new approach to standardized testing, one that combines a primary focus on criterion-referenced achievement with significant aspects of construct-based ability testing" (p. 3). Examinees use calculators on the test and are given a reference page that includes all the formulas needed to complete the assessment. The Work Keys assessment contains 30 multiple-choice questions that increase in difficulty. The testing time is 40 minutes. According to McLarty (1992), "WORK KEYS assessments are unabashedly achievement oriented and include only skills that can be taught" (p. 3). Work Keys is reported to students as level 3 through level 7 skill attainment. The coefficient of reproducibility ranged from .87 to .88 and the coefficient of scalability ranged from .56 to .58 (Vansickle, 1992). However, for this study, "number right" scores were also obtained from ACT to provide interval data needed for an analysis of covariance procedure.

P-ACT + ASSESSMENT A traditional standardized math assessment was administered to each student using the mathematics portion of the P-ACT+ assessment from the American College Testing Service. This instrument was designed primarily to help determine student preparedness for further education. The P-ACT+ tests have both a content and an empirical relationship to the ACT Assessment. The P-ACT+ measures student development in the same curriculum areas as the ACT assessment with the exception that it measures these skills at 10th grade level (American College Testing, 1992). Specifically, "it emphasizes the ability to solve practical quantitative problems that are encountered in many first-and second-year high school courses" (American College Testing, 1995, p. 5).

The mathematics portion of the P-ACT+ test is a 40-item, 40 minute test that measures the student's level of mathematics achievement (American College Testing, 1992). The reliability for the Pre-Algebra and Algebra sections ranged from .75-.86. The standard error of measurement was given as 1.18-1.57 for the Pre-Algebra/Algebra subscore (American College Testing, 1995).

The P-ACT+ Pre-Algebra/Algebra subscore has a predictive correlation with high school coursework and grades of .56 using multiple regression (American College Testing, 1995). Thus, P-ACT+ scores are statistically related to high school coursework and grades in math. However, it should be noted that P-ACT+ is designed to reflect skills taught in Pre-Algebra, Algebra, and Geometry courses. While the CORD material contains many of these competencies, the methods by which they are taught, may not be reflected well in P-ACT+. As such, one could argue that P-ACT+ Pre-Algebra/Algebra assessment is well suited for individuals taking traditional algebra courses but not intended to measure mathematical concepts in a contextual, applied setting.

THE PURDUE MASTER ATTITUDE SCALE TOWARD SUBJECT MATTER

The group-administered Math Perception Survey was modified from the Purdue Master Attitude Scale Toward Subject Matter by Remmers (1934). The 7-point Likert-type scale uses brief statements in both positive and negative form that require the subject to select an answer ranging from Very Strongly Agree to Very Strongly Disagree.

Modifications of the instrument included replacing the words "subject matter" with "math". The twenty item scale was shortened by McCaskey (1987) from the original 90 items. The shortened version of the Purdue Master Attitude Scale yielded a Cronbach's Alpha estimate of internal consistency of .95 throughout this study. McCaskey (1987), likewise, reported a .95 internal consistency during his study.

DESCRIPTIVE SURVEY

An instrument was developed for this study to gather descriptive data about the participants. These data were used to provide a basis for assessing homogeneity among groups. The group-administered student information survey was used to collect information about grade, gender, previous math success, class assignment, and intention after graduation.

PROCEDURE

Data were collected in late April of 1995 as students completed course requirements. The collection of data took two class periods. The first data collection involved assessing workplace mathematics skills of all participants using the Work Keys work-readiness assessment in math from ACT in addition to administering a descriptive survey to obtain participant information. The second data collection component took place the following day using the Pre-Algebra/Algebra subscores of the mathematics portion of the P-ACT+ Test from ACT and a modified version of the Purdue Master Attitude Scale Toward Subject Matter.

School counselors then supplied coded individual mathematics and reading scores on the state mandated Missouri Mastery Achievement Test (MMAT) given to all eighth grade students. The MMAT was selected as a possible covariant because it was the only test providing a common data base among the four schools. The General Linear Models (GLM) analysis of variance procedure indicated that a significant difference existed among MMAT scores in both reading and math. Therefore, the three sample groups were not homogeneous and the GLM analysis of covariance procedure was used to analyze the data to control statistically for the difference in entry skills. Thus, test scores after the treatment could be adjusted to reflect the influence of the treatment more accurately.

DATA ANALYSIS

The General Linear Models (GLM) analysis of variance procedure was used to determine if significant differences of mean MMAT scores existed among the groups. The strategy of the analysis of variance is to compare the actual mean difference observed with the difference expected by chance (Gay, 1992). GLM procedures were used throughout the study in lieu of standard analysis of variance and covariance because of the unbalanced design. All data analyses were performed by computer using a SAS statistical package (SAS Institute Inc., 1989). Data for objectives one and two were analyzed using the GLM analysis of covariance procedure and data for objective three were analyzed using the GLM analysis of variance procedure. The related hypotheses were tested at the .05 alpha level. The least square means procedure was used for post hoc analyses.

FINDINGS

Descriptive data and eighth-grade MMAT scores were examined to ascertain profiles of students in the three classes. Most (224) of the students were in either grades 9 or 10. The composition of the groups was 58% male for applied math and 56% female for algebra 1. When asked which best described their last math class, nearly half of the students in applied math 1 responded 8th grade general math. However, 76% of the students in algebra 1 selected pre-algebra/algebra (see Table 1).

Students also reported the grades usually received in math class. As reported in Table 2, algebra students reported higher grades in previous classes.

Eighth-grade Missouri Mastery Achievement Test (MMAT) scores in reading and mathematics were a significant component of the data sets. These scores were obtained from counselors at the schools and are shown in Table 3.

The General Linear Models (GLM) analysis of variance procedure indicated that a significant difference existed among MMAT scores in both reading and math. Least Squares Means (LSMeans) showed that a significant difference existed between MMAT scores for students in algebra 1 and those in applied mathematics 1 and 2. However, there was not a significant difference between scores for students in applied mathematics 1 and 2.

The unadjusted and adjusted mean scores for students in the three groups for the Work Keys and the P-ACT+ are presented in Table 4.

Using procedures provided by ACT (1995), the unadjusted mean P-ACT+ subscores were rounded to the nearest whole number and converted to a scaled score. For the three groups, the P-ACT+ scaled subscore was 6 for both applied math groups and 8 for the algebra 1 group. This scaled subscore is not terribly meaningful with the exception that it provides a basis of comparison with a 1992 national sample of 10th grade students. According to ACT (1995), a scaled subscore of 6 puts the Missouri applied mathematics sample group at the 46th percentile, roughly right in the middle of all 10th graders in the ACT sample group. The algebra 1 group fell in the 71st percentile.

The first objective was to compare the performance of students completing applied mathematics 1, applied mathematics 2, and algebra 1 courses on the Work Keys assessment. The data indicated there was no significant difference among mean scores on the Work Keys Applied Mathematics test for students completing applied mathematics 1, applied mathematics 2, and algebra 1 after adjusting for 8th grade MMAT scores through the use of a GLM analysis of covariance procedures ($F=0.32$; $df=4/249$).

The second objective was to compare the performance of students completing applied mathematics 1, applied mathematics 2, and algebra 1 courses on the P-ACT and pre-algebra/algebra assessment. A GLM analysis of covariance procedure revealed that there were significant differences among adjusted mean scores on the P-ACT+ and Pre-Algebra/Algebra subscore ($F=9.14$; $df=4/249$). The posthoc analysis indicated that there was no significant differences between the mean score of students in applied math 2 and students in algebra 1 on the P-ACT+ Pre-Algebra/Algebra subscore when adjusted on MMAT reading and mathematics score (see Table 5). Likewise, no significant difference was indicated between the mean score of students in applied math 1 and students in applied math 2. However, a significant difference existed between the mean score of students in applied math 1 and students in algebra 1 on the assessment's Pre-Algebra/Algebra subscore. This difference was in favor of students in algebra 1.

Objective 3 was formulated to determine if the level of student perception about mathematics as a school subject differed among students in the three types of mathematics classes. A GLM analysis of variance procedure was performed on the perception data of the three groups. The mean score for students in applied math 1 was 4.61. The mean score for students in applied math 2 was 4.63. The mean score for the students in algebra 1 was 4.89. There was no significant difference ($F=2.05$; $p=.13$) among these scores at the .05 alpha level.

SUMMARY OF FINDINGS

Based upon the three objectives of this study the following were the main findings:

1. There was no significant difference in performance among students taking applied math 1, applied math 2, and algebra 1 on the Work Keys assessment.
2. There was a significant difference between the scores of students in applied math 1 and algebra 1, in favor of the latter, on the P-ACT pre-algebra/algebra subscore.
3. There was no significant difference between applied math 1, applied math 2, and algebra 1 students with respect to perceptions of mathematics.

CONCLUSIONS

The following conclusions are suggested by the main findings:

1. Students completing applied mathematics 1 and students completing applied mathematics 2 should make comparable progress in developing math skills to students completing algebra 1 as assessed by Work Keys.
2. Students completing the second year applied mathematics course should make comparable progress in developing math skills to students completing algebra 1 as assessed by the P-ACT+. Students completing the first year of applied math probably will not make comparable progress with students completing algebra 1.
3. Students completing applied mathematics 1 and students completing applied mathematics 2 possess comparable perceptions toward math as a school subject as students completing algebra 1.
4. Instruction based on the CORD Applied Mathematics curriculum is useful for students who learn using applied, activity-centered approaches.

DISCUSSION

The findings of this study are consistent with the CORD (1994) study and the Tanner & Chism (1996) study that found that the students completing applied math 2 attain comparable skills to students completing algebra 1. The results of this study are important to educational decision makers as they judge the success and value of courses emphasizing an applied or contextual approach. The evidence suggests the applied courses prepare students for additional study in high school or for college entry level courses. It should be noted, though, that students completing algebra 1 performed better than those completing applied math 1 on the P-ACT. But the relatively high scores on algebra 1 might be explained by selection bias, given the significantly higher scores of these students on the reading and math pre-tests.

The results of this study lead to several areas of discussion. Isolating curriculum and instructional strategies in educational research is very difficult because of external factors such as class selection by students and previous experience in mathematics. As such, statistical control and qualitative judgments were necessary to aid in interpreting the findings.

Many teachers were excited about the interest and progress that students displayed using the applied approach. It was difficult, however, to relate these observations directly to performance progress data because of confounding variables. A concern raised early in the study involved the entry skills of students enrolling in applied math. Use of 8th grade Missouri Mastery Achievement Test (MMAT) scores in reading and math as covariant variables provided a method to statistically adjust mean scores for entry skills, allowing a more meaningful assessment of student progress as a result of class instruction and curriculum.

The comparable math progress that was made by the applied mathematics 2 group when compared to the algebra 1 group may well be attributable to the contextual and associative learning theories described in the theoretical base section. The CORD Applied Mathematics curriculum provides for a hands-on approach that actively engages the learner. Specific activities such as popping corn and calculating the percent of popped kernels may be used as contrasted to a traditional approach of working problems from a guide sheet. As stated earlier, "cognitive learning theory views the learner as a very active participant in the learning process" (Royer & Allen, 1978). Applied learning proponents frequently mentioned that some students truly comprehend only after active participation. For some, construction in the classroom through psychomotor should precede construction in the cognitive. These students often prefer to learn through hands-on, activity centered projects like those used in applied math.

Further consideration of student performance on the Work Keys Applied Mathematics assessment also raised questions.

Surprisingly, the first and second year students in applied math did not score significantly different on the Work Keys exam. Although no hypothesis was developed comparing the scores of the two groups it might be assumed that the second year group would score better than the first. One explanation could be that Work Keys Applied Mathematics is designed to assess job entry behavior and primarily addresses only those skills covered in the first 15 units of CORD Applied Mathematics.

The data gathered about perceptions toward math as a school subject were also examined. Despite less success in math as indicated by 8th grade MMAT scores and the self-reported math grades received, the students in the applied math classes perceived math to be as useful a school subject and valuable in life as the students in algebra 1. Personal interviews with teachers revealed a renewed interest in math among students in applied mathematics classes. Therefore, the similar perceptions may have been influenced by the contextual nature of the applied classes and the success realized by these students.

Educational leaders as well as local school districts should be better prepared to make informed decisions concerning the use of applied mathematics courses. The positive performance of students in these courses has been documented, providing decision makers additional information needed to help derive reasoned conclusions about the role of contextual approaches in education.

Added material

Table 1. Percentage of Students Reporting Last Math Class in which Subjects were Enrolled

	9th/10th grade general math	Applied math 1	8th grade general math	Pre-algebra algebra
Applied math 1	8%	8%	46%	38%
Applied math 2	7%	61%	0%	

Table 2. Percentage of Students Reporting Grades Received in Math Class

	A's	B's	C's	D's/F's
Applied math 1	9%	35%	47%	9%
Applied math 2	7%	46%	39%	7%
Algebra 1	23%	42%	25%	10%

Table 3. Group Means of Eighth Grade MMAT Reading and Mathematics Scores

	Mathematics	Reading
Applied math 1	287	286
Applied math 2	299	294
Algebra 1	372	331

Table 4. Unadjusted and Adjusted Mean Work Key Scores, Work Keys Levels, P-ACT+Pre-Algebra/Algebra Subscores for students in Applied Math 1, Applied Math 2, and Algebra 1

	Work Keys			Prealg/Alg	
	Unadj.	Level	Adjusted	Unadj.	Adjusted
Applied math 1	18.1319	4.1798	19.2438	7.8901	8.7940
Applied math 2	18.8780	4.2821	19.6562	9.2195	9.8512
Algebra 1	20.1230	4.4790	19.0320	11.8934	11.0068

Table 5. Probability of Significant Differences Among the Least Squares Means for PACT+Pre- Algebra Scores

	P-ACT+ LSMEAN	Pr>T	HO: LSMEAN = LSMEAN		
Group			1	2	3
Applied math 1	8.794	1	xxxxx	0.0799	0.0001
Applied math 2	9.851	2	xxxxx	xxxxx	0.0637
Algebra 1	11.006	3	xxxxx	xxxxx	xxxxx

FOOTNOTES

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