To the Graduate Council:

I am submitting herewith a dissertation written by Mary R. Daunis entitled "The Validity of Placement Testing in Freshman Mathematics at The University of Tennessee, Knoxville." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

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THE VALIDITY OF PLACEMENT TESTING IN FRESHMAN MATHEMATICS AT THE UNIVERSITY OF TENNESSEE, KNOXVILLE

A Dissertation

Presented for the

Doctor of Philosophy

Degree

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Mary R. Daunis

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ABSTRACT

Methods of determining the best entry level mathematics course for college students vary greatly. Most commonly, test scores determine placement. Either a test designed specifically for placement or the score on some achievement test, such as the ACT or SAT test, is used. Historically, results have been less than satisfying , characterized by low correlations between predictor variables and student success rates.

This research focuses on finding a collection of predictor variables which can be used to determine the proper placement of college students into their entry level mathematics course. Several sections of various freshman level mathematics courses at the University of Tennessee, Knoxville (UTK), were selected at random for participation in the study. Students in those classes were given two placement examinations published by the Mathematical Association of America during the first week of classes in the fall quarter of 1987. Other pertinent data, including the high school from which each subject graduated, the number of credits in high school mathematics, mathematics score on the ACT test, and high school grade point average, were collected from the Office of Student Data Analysis at UTK.

We found low correlations between predictors and measures of student success. Prediction equations were obtained which accounted for as little as 20% and as much as 50% of the variance in grade. In addition, we found that a certain amount of sex bias appears to exist in the placement tests used; this bias results in low placement for females although they outperform males in the same mathematics courses.

We recommend the use of several predictor variables in determining placement rather than relying on one placement test score. Finally, we feel that the use of different cut-off scores to determine placement for males and females should be investigated.

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CHAPTER 1

INTRODUCTION

1. INTRODUCTION TO THE STUDY

The problem of placing college students into an entry level mathematics course has received increasing attention in recent years, and mandatory testing and placement procedures have been studied as solutions. As Weber (1985) points out, students deserve a fair chance to succeed in college as they enter the "open door," and accurate placement increases the chance of success (Worner, 1977). Placing students into classes for which they are best prepared means that teachers are not trying to teach material which is beyond their students' level of understanding. Thus, the teaching/learning environment is improved: students are not "doomed to fail" from the beginning.

We will define a placement process in mathematics as one which examines measures of student mathematical achievement and ability by high school records and test scores, and determines from this the entry level mathematics course which most closely matches the student's mathematical level of achievement. The purpose of placement is to find the course which best matches the student's cognitive level in mathematics and optimizes the student's chance for success. If the placement is valid, then a high proportion of students who take the prescribed course should subsequently be judged successful in the course on some established criterion, such as course grade or a pass/fail categorization, where a grade of C or better is categorized as pass, and other grades are categorized as fail.

Several events can occur as this procedure unfolds. Students who are predicted to pass and then actually do pass are cited as evidence that the placement procedure works. Similar conclusions are drawn when students predicted to fail actually fail. Students predicted to fail but who are able to pass and those who are predicted to pass but then fail the prescribed course are not well served by the placement process for some reason. Their improper placement wastes valuable time and resources of both the student and the school. An effective placement procedure should minimize the number of students in these groups. A placement procedure may be deemed successful when the number of correct predictions is greater than the number of incorrect predictions. How much "greater" is a matter of contention. The ideal situation would be to have all predictions correct. However, a more realistic apportionment is shown in Figure 1.

		PREDICTED OUTCOME	
		Fail	Pass
ACTUAL OUTCOME	Fail	75%-85%	15%-25%
	Pass	15%-25%	75%-85%

FIGURE 1. APPORTIONMENT OF PREDICTED VS. ACTUAL OUTCOME

Accordingly, we will define a placement process to be effective if it correctly predicts success or failure for 75% to 85% of students.

Accepting for the moment that a placement procedure of some kind is desirable, the question becomes one of determining the effectiveness of such a procedure once it is in place. Our research is concerned with the evaluation of the placement procedure in mathematics at The University of Tennessee, Knoxville. The study was motivated by certain questions the Mathematics Department had concerning its placement program. Specifically, is the placement testing procedure working and would it be cost effective to continue the program? In addition, should students be required to take the tests and then to follow the placement recommendation resulting from those tests? Finally, in setting cut off scores, should a student's sex, high school type (rural or urban), and high school size be considered?

We are also interested in discovering what changes can be made to improve the results of the placement process. Comparing students' predicted performances with their actual performances in their mathematics classes can reveal possible errors in placement. We examine as possible causes for such error sex bias and high school size or location, as well as certain unpredictable causes which characterize individual students and influence their performance. To try to determine whether the addition of other variables can improve the process, we present a linear model based on ACT mathematics scores, high school grade point averages, placement test scores, number of high school mathematics credits, and student's sex.

We would like to be able to say that 70% of the students we predict to pass will actually pass, and that about half of the remaining 30% should have passed but failed due to some unpredictable circumstances. This means that 85% would have been correctly placed. Furthermore, we would like to have only

about 25% of those predicted to fail actually pass, with 5% of those (or a little over 1% of the total group) attributing their success to some extraordinary efforts of their own.

We calculated the number of subjects who fell into each of the four groups illustrated in Figure 1. We generated prediction equations using placement test scores, high school records (including high school grade point average, number of mathematics credits in high school, high school size and location), ACT mathematics test subscore, and sex.

2. BACKGROUND OF THE STUDY

Determining a student's achievement level in mathematics has most commonly been done in three ways: examination of high school records, using standardized test scores (such as the ACT or the SAT) measuring achievement and ability, and using placement tests designed specifically for the purpose of making placement decisions. On the basis of these criteria, used either individually or in combination, a judgment is made as to the level of mathematics at which a student is most likely to succeed without at the same time being underchallenged. A placement decision is then made and the student is advised to take a prescribed course. In a sense, the student is given a tacit prediction that he or she will pass the course recommended by placement and will fail any higher level course. But there are shortcomings inherent in any placement process which relies on a single test score to determine a student's optimum entry level mathematics course, especially since many factors affect the ability of students to succeed.

For example, differences in mathematics achievement based on sex are well-documented in the literature. Several studies reveal that high school females obtain better grades than high school males, while high school males score higher than females on standard achievement tests (Pallas and Alexander, 1983; Decore, 1984). Nevertheless, at the college level males and females tend to be more equal in grades. One explanation offered is the degree of selection of females for college which occurs. Only the "best and brightest" females continue in college and so they should be expected as a group to equal or even surpass their male counterparts. If we accept the premise that differences exist in mathematics achievement based on sex, then we should expect differences in mathematics placement. Since mathematics achievement is generally measured by some standardized test, and since scores on such tests are often the basis for placement decisions, then it could be hypothesized that males, who tend to score higher than females on such tests, are placed higher than females even though females tend to receive equal or better grades than males in comparable courses. The result would imply that females are placed too low by placement exams. In this study, we compare the placement and subsequent performance of males and females to test the hypothesis stated above.

Certain characteristics of one's high school may also affect performance on placement examinations. Factors such as size and geographic location of one's high school may result in differences in placement. Do significant differences occur in mathematics placement when these qualitative differences in high school background are considered?

A further shortcoming of most placement validation studies is that subjects are not randomly assigned to treatment groups. For this reason, results may

reflect the fact that students tend to enroll in courses for which they already expect to be successful. This tends to limit the range of scores on the placement test and may cause correlations between predictors and criteria to be decreased.

Another common aspect of such studies is their almost complete reliance on predicting success in a course based on variables exclusively from the cognitive domain. In fact, most validity studies have taken the form of correlational research studies where test scores and other quantitative measures of mathematics achievement or ability are correlated with some criterion, usually overall grade point average. Correlations in the range of 0.20 to 0.70 have been reported in these various studies (Passons, 1967 and Weiss, 1970), representing significant predictive ability for the test or set of tests studied. Few studies have undertaken to measure the correlation between predictors and specific mathematics course grades.

Two questions arise from these facts. First, do students who have been placed in a mathematics class by some procedure outperform their cohorts who are in the same class without benefit of having been through the placement process? This question relates to the non-randomization issue. Second, what can be gained by studying the effect of certain noncognitive variables on placement decisions? These are variables which are neither affective nor cognitive in nature (Begle, 1979). In particular, what influence do sex of the student and characteristics of the high school exert on placement? This study is an attempt to further the research in these areas.

3. NEED FOR THE STUDY

Placement of college students into the entry level mathematics course for which they have optimum chance for success and minimum chance for boredom has become increasingly difficult in the past two decades. Several factors have contributed to this problem. An increasing number of students entering college need remedial work. Simultaneously, the best high school students have increased the level of work they can do as evidenced by the increase of advanced placement in mathematics programs in the high schools. Finally, the number of entry level college courses available for students to take has increased. With so many choices available, making placement decisions has become more difficult (User's Guide: The Placement Test Program of the Mathematical Association of America, 1984).

For several years prior to the study, the Mathematics Department at The University of Tennessee, Knoxville, experimented with using the Advanced Algebra and Calculus Readiness tests published by the Mathematical Association of America as placement tests for entry level mathematics courses. Students were advised to register for a particular mathematics course based on their score on one of these tests, and certain cut off scores grew out of this process. The tests were chosen primarily for convenience, and the question arose as to how well the process was working. In particular, the administration wished to know what percentage of students taking the recommended courses were then succeeding or failing at those courses, what percentage of students taking higher level courses than the ones recommended were succeeding or failing, and whether the results could be improved if other information on student

achievement and background were incorporated for use in the placement decision. In addition, the administration wished to know if the cut off scores were at the best setting. Hence, this study was undertaken as an attempt to investigate the validity of the placement procedure in mathematics at The University of Tennessee, Knoxville.

4. STATEMENT OF THE PROBLEM

Even with a highly effective placement process, and one which utilizes both cognitive and noncognitive variables in the placement decision, as many as 50% of students can be misplaced, either by succeeding where failure was predicted or by failing where success was predicted. What collection of student data results in the most effective predictor of success in a mathematics course? Can placement decisions be made more effective when other variables are included? Are other variables better alone or in combination with the placement test score?

As we have seen, research indicates that females tend to receive higher grades than males in the same mathematics course, in spite of the fact that females' standardized test scores are lower than males'. Are females unfairly placed into lower level mathematics courses than males when standardized tests are used for placement?

Some research identifies a tendency for high school size to be a factor in students' success in college mathematics courses, but results are conflicting, with some finding no difference in academic performance due to high school characteristics and others finding small differences. But, even when differences

are found, no trend favoring one type of high school over another is clearly documented. (Thornberg, 1924, Dwyer, 1938, Hoyt, 1959, and Lins, 1954). Are students from schools with smaller enrollments or from rural areas unfairly placed into lower level mathematics courses than students from larger schools located in urbanized areas?

5. RESEARCH HYPOTHESES

The predictor variables studied were the Advanced Algebra and Calculus Readiness placement test scores, high school grade point averages, ACT mathematics subscore, and high school mathematics credit. The criteria were college mathematics course grade, posttest score, and success in the college mathematics course. The research was guided by the following research hypotheses:

1. Correlations among the selected predictors and criteria are significant.
2. Prediction equations can be established by multiple linear regression of the predictors which can account for eighty percent of the variance in grades.
3. The placement of students into an entry level college mathematics course using the Advanced Algebra and Calculus Readiness placement examinations published by the Mathematical Association of America is not affected by the student's gender or by the size and geographic location of the student's high school.

6. ASSUMPTIONS

We make the following assumptions:

1. The mathematics subscore of the American College Testing Program examination is a valid and reliable measure of achievement in high school mathematics. This test is administered to high school juniors or seniors under conditions assumed to conform to those recommended by the publishers of the test and is free of ethnic or sex bias.

2. The characterization of a high school's location as rural or urban based on information obtained from the Tennessee Statistical Abstract (1988) or based on the opinion of a school's principle or guidance counselor is reliable and reflects the approximate population and proximity to urban areas.

7. SCOPE AND LIMITATIONS OF THE STUDY

Subjects who participated, both students and teachers, were volunteers. The results may have been affected by the small number of students who were willing to participate. Subjects were not randomly assigned to classes, but classes which participated were randomly selected form among all classes. In this light, results may be applied to college students in entry level mathematics courses.

8. ORGANIZATION OF THE STUDY

This study is organized into five chapters and three appendices, as follows:

Chapter 1 includes an introduction and some background to the study. The need for the study is explained and a statement of the problem is given. The assumptions made in conducting the study are listed, along with the scope of the study.

Chapter 2 provides a review of the literature related to the study of placement in college mathematics courses. Also included are studies dealing with differences in mathematics achievement based on sex and high school type.

Chapter 3 describes the methods and procedures utilized in the study and includes the presentation of tables generated as a result of the data collected. The statistical tests employed are also briefly described.

Chapter 4 presents an analysis of the data.

Chapter 5 presents findings, conclusions, and recommendations. Also included are implications and possible avenues for further research.

The three appendices contain copies of the consent forms used in the study, the Advanced Algebra and Calculus Readiness placement exams, and the posttests used for each mathematics course.

CHAPTER 2

REVIEW OF RELATED LITERATURE

1. INTRODUCTION

Testing for placement into college level courses had its beginnings in the early part of this century when military demands of World War I and World War II necessitated the screening of recruits. The process carried over quite naturally into the academic world where a rise in standardized testing occurred which continued into the 1960's when the movement of student rights posed both legal and ethical questions of test bias. The resistance to testing grew and, with the added tendency toward decreasing enrollments, a decline in standardized testing began (Rounds and Anderson, 1985).

The scene today, however, represents a change from this disenchantment with testing. As more students from the lower half of the socioeconomic ladder sought higher education through the "open door", colleges became increasingly populated with students who performed in the lowest third on tests of academic ability (Cross, 1974). Faced with decreasing enrollments and increasing competition for students, universities felt the need to widen the "open door". As more nontraditional students, many of whom were at high risk of failure, began to go through the "open door" it became apparent that new measures undertaken to reduce student failure rates would be required. (Rouche and Archer, 1979). Adding the combined influences of declining ACT and SAT scores, a renewed emphasis on basic skills, and calls for accountability from the educational community, many colleges and universities in the seventies found themselves returning to the practice of testing for both admission and placement. The result has been that such

programs have become mandatory in many states, including the university systems of Georgia, New Jersey, Florida, and California (Rounds and Anderson, 1985). Since the 1970's, thirty-eight states have adopted some sort of program to assess the basic competence of students (Poggio and Glasnapp, 1981).

Friedlander (1982) found that among community colleges in the late 1970's there was a growth in remedial programs and testing of students for placement into and out of these programs. The trend for such colleges was to no longer allow students unbridled freedom to enroll in any course. While such a course of action does not guarantee success to students there is at least a better chance for students to receive instruction at a level close to their own skill level (Worner, 1977).

Such rapid growth in the use of tests for placement has resulted in some abuses by well-meaning university personnel. Doblin (1978) points out that nearly all universities require a standardized test score of some type for admission and that many use the scores for placement against the recommendation of the test developers. In particular, Johnson (1984) decries the use of the SAT test for such purposes:

> SAT scores are useful in student assessment and national comparison, but are impractical for placing students in specific college courses. In fact, SAT scores are not purported to project such depth of perception that would enable admissions personnel to select courses for students. (p. 8)

In his review of literature related to the placement testing movement, Rounds (1984) documents a dramatic increase in the use of entrance assessment, with growing interest in finding tests which can accurately predict

a student's performance. The trend is for such testing to be mandatory for purposes of assessment and placement, particularly into English and mathematics courses. A wide variety of tests, both standardized and locally developed, were found by Rounds (1984) to be in use. Rounds and Anderson (1985) cite several studies reporting gains in both retention and grade point averages for students who were placed into courses at their skill level as determined by such tests. However, they caution that placement decisions should not be based on just one test score; a combination of testing and counseling is recommended by these authors.

The placement movement has been motivated by several factors which have combined to make testing for assessment necessary. College students today are characterized by diversity in backgrounds, learning styles, and preparation. According to Callas (1981), "the federally financed National Assessment of Educational Progress has estimated that thirteen percent of 17-year-olds still in school could also be classified as functionally illiterate" (p. 27). The "open door" contributed to this situation as such students found themselves in college perhaps ill-prepared to perform at the level of expectation. Pearse (1982) refers to "an increasing number of students who have not been adequately prepared by our education system over the last 15 to 20 years" (p. 4), and quotes statistics which show that inadequate preparation accounts for the majority of students' dropping out of college. Weber (1986) gives placement a dual purpose of identifying both the underprepared who need extra assistance and the well-prepared who can better begin study at their optimum ability level, thus increasing the chance for success in the first case and decreasing the boredom level in the second case.

Weber (1986) concludes his review of research in placement with the following strong recommendations:

> Content-specific placement tests in combination with other data will yield effective assessment forming a basis for placement decisions. Performance on general achievement tests (ACT or SAT) or a subsection of one achievement test should not determine basic skills course placement. . . . For evaluation of course placement schemes standard evaluation procedures such as validity tests should be supplemented by surveys of students and faculty and analysis of placement-enrollment consequences. (p. 28)

In spite of this admonishment from Weber, many universities continue to use tests for placement which were intended to be used for entrance assessment.

2. THE SEARCH FOR PREDICTORS AND TESTS

The majority of studies dealing with placement into college mathematics courses are correlational studies, where the researcher attempts to establish that a set of tests or other achievement measures are the best predictors of success or grades. A major shortcoming of most of the research is its failure to allow for random placement of subjects into treatment groups. Another problem is the use of tests whose content does not closely match the course into which the students are being placed. General tests such as the SAT or the ACT are often used to predict achievement in mathematics courses, but the writers of these tests themselves deem this use as inappropriate.

Lavin (1965) reviewed the literature and found a lack of studies using content-specific placement tests to predict achievement. In a study by Goolsby (1966) using second semester sophomores at Florida State

University, none of the predictors correlated well with junior grade point average. The predictors used included Florida Twelfth Grade Achievement Tests, School and College Ability Tests (SCAT), Comprehensive College Tests, and sophomore cumulative grade point average. The reported range of correlations with sophomore GPA was 0.30 for the ACT Natural Science and Mathematics subtests to 0.45 for the Comprehensive College Tests English subtest. A prediction as general as junior grade point average is difficult to make by any measure.

The search for an assessment variable that has acceptable predictive ability goes on. Even correlations of up to 0.70 fail to account for as much as 51% of the variance in grades. Attempting to find a solution, many colleges use high school records and other achievement records to assess incoming students. But differences of grading among high schools make reliance on such academic records risky. Even locally developed tests are subject to questions of validity and reliability, and most colleges lack a sufficient data base to perform such studies (Callas, 1985).

Indeed, the majority of recent research on the prediction of success in first year college mathematics courses has dealt with relating success to previously taken measures of academic achievement such as high school grade point average, placement test scores, achievement test scores, and psychological test scores (Bohannon and Smith, 1978). This ignores two issues raised by Cronbach. First, valid prediction depends upon a close match between the testing process and the real life situation to which results are applied. A study by Passons (1967) illustrates this point. The results of that study indicated that high school grades correlated higher with semester GPA than with specific mathematics course grades, while SAT and ACT

composite scores showed the highest correlations with specific mathematics course grade. The mathematics scores for each of these tests were the next best correlates. However, the subjects in the study were presumably all of somewhat high ability since all were in a calculus course. The second issue raised by Cronbach concerns bias in the criterion used to make predictions. Hence, the predictors used should be specific to the outcome to be predicted, which itself must be measurable with some certainty. Since the predictors taken from one group are ultimately applied to another group, the importance of a good match is evident (Cronbach, 1971).

Richards, Holland, and Lutz (1967) used subjects from a range of ability levels in their study of the correlation of ACT score and high school grades with college grades. They found that high school grades were more consistent than ACT scores as a predictor of academic achievement as measured by college grades, while a weighted combination of high school grades and ACT scores was even better. However, the median individual correlations were low, with a reported correlation of 0.29 for ACT and college grades (8% of the variance in grades) and 0.38 for high school grades and college grades (14% of the variance). The best predictors still leave a great deal unaccounted for.

Slightly better results were obtained by Munday (1967) in a study of 176,779 students from 379 colleges and universities participating in the ACT Research Service in 1963, 1964, or 1965. ACT scores and self-reported high school mathematics grades were correlated with college mathematics grades in this differential prediction study and a median multiple correlation of 0.521 was reported, which accounts for 27% of the variance in college grade. Munday (1968) later found using a different sample that ACT scores

correlated highly with other intelligence measures, scholastic aptitude, and English and reading achievement.

A study by Bridgeman (1982) also concludes that general aptitude tests are better suited for selection than for placement, and that their use in placement is inappropriate. Concordance between the test used and the use to which the test is applied results in more accurate predictions of success. An example of a study which violates both the principles cited by Bridgeman is Aleamoni and Oboler (1978). Using students from a highly selective midwestern university (N = 4283), they reported correlations of the mathematics subscore of the ACT, the total ACT score, mathematics subscore of the SAT, the total SAT score, and the high school grade point average with first semester college grade point average of 0.221, 0.267, 0.228, 0.290, and 0.429, respectively. Predicting first semester grade point average using only high school grade point average with the attractive correlation of 0.429 still accounts for only 18% of the variance; the addition of five more predictors to the model only improved the correlation by 3% and accounted for a total of 21% of the variance. Such global predictions as semester grade point average are difficult to make with the predictive measures currently being used. Weiss (1970) also tried global prediction of semester grade point average and also concluded that high school grade point average was the best predictor of success in college. However, Weiss goes on to say,

> The highest obtained correlations between predictors and GPA approach only .7 and this magnitude of correlation is found only when the variables employed and the particular college programs involved are uniquely adapted to each other. Correlation coefficients of this magnitude account for less than half of those factors influencing the GPA. It is therefore reasonable to attempt to organize the variables into a formula which will account for a larger percentage of the variability. (p. 204)

Based on his arbitrary feelings of the degree of significance of each variable, Weiss assigned weights to them to improve the correlations between predictors and grade point average. The result was a formula which accounted for more of the variance in grade point average, but the choice of numerical values for the weights used seemed contrived.

The most recent trend in placement testing studies is away from such global prediction and toward differential prediction. Such studies are characterized by their use of specific course grades rather than overall grade point averages and the use of tests which are concordant with the target course (Fowler and Ross, 1982). Troutman (1978) did one such correlational study. All four variables used, namely IQ on the Stanford Binet Intelligence Scale, high school rank, SAT mathematics subscore, and high school mathematics grade point average, were significantly correlated with final grade in a finite mathematics course, and stepwise regression analysis including all four predictors accounted for 37% of the variance in course grade. However, the danger of using high school grades in prediction lies in the fact that students from different high schools with similar grades have widely different college grades, thus potentially reducing their validity when used for placement decisions (Travers, 1949).

Suddarth and Wirt (1974) did a study which made a good case for differential prediction. Using 5000 incoming freshmen and a combination of precollege data and achievement test data from the College Entrance Exam Board, they found that adding achievement test scores to the prediction equation added little to their predictive ability, except in chemistry. Prediction of specific grades in given subject areas of English, mathematics, and

chemistry accounted for 62%, 55%, and 69% of the variance in grades, respectively. The predictors used were percentile rank in high school class, expected high school semesters to be completed in each subject area, average grade in courses already completed, and average grade in all subjects. However, when students were divided into low, middle, and advanced groups, the correlations between predictors and course grades fell sharply, due perhaps to the previously cited fact that students from different high schools with similar high school grades often get very different college grades.

Peters and Plog (1961) compared the ACT to a locally developed mathematics placement test in a sample of 2705 freshmen at Ohio State University. After an initial screening test, students were placed into low, middle, or high groupings and tested a second time for placement. Thus, the range of placement test scores was limited within courses. For the highest and lowest groups, the local test displayed the optimum correlation with grade, while for the middle group, the ACT test correlated higher. These differences occurred in spite of the significant and high (0.86) correlation between the ACT and the local test. A ceiling effect may have been in operation which resulted in preference for ACT within the middle group.

3. THE EFFECT OF HIGH SCHOOL CHARACTERISTICS

School size has frequently been studied as one factor contributing to differences in college grades among students, but with often contradictory results. An early study by Thornberg (1924) found superior scholarship in college among students from larger high schools. But Thornberg gives no

tests of significance to support his findings. In a review of the literature Dwyer (1938) was led to hypothesize the existence of a significant positive correlation between high school size and first semester grades in college, with a decrease in the significance of this correlation as time went on. In addition, Dwyer found that more students from small schools leave college after the first semester than those from larger schools, while persisters from small schools are as good academically as persisters from larger schools. Students from smaller schools tended to have lower academic averages in the first semester than students from larger schools. But, since more of these students drop out after one year, it is not surprising that the difference becomes smaller by the junior year and thereafter almost disappears. Dwyer concludes that while the relationship between high school size and academic success in college has been established, it is not "definite enough to serve as the basis of individual prediction" (p. 278).

First year differences in college grades between students from large and small schools were also found by Bledsoe (1954), with students from larger schools obtaining significantly higher marks than those from smaller schools. On the other hand, Lins (1954) in a study of 2000 University of Wisconsin students found no significant difference between the means on the American Council on Education Psychological Exam (ACE) among students from small and large schools. Hoyt (1959) found conflicting results in previous studies relating to size of high school and college grades, and poses that high school rank might better be interpreted differently depending on high school size. Also, Hoyt found that correlations between high school rank and grade point average were inconsistent in that some were higher among students from larger schools while some were the same no matter the size of the high

school. The explanation offered by Hoyt is that these studies lack controls for academic ability and sex differences and fail to report tests of significance. In his study, Hoyt examines the data for males and females separately and finds no significant differences on either the ACE or grade point average, even though females tended to have higher grade point averages than males. Interestingly, the average high school size tended to vary less among females than among males. High school rank for females tended to decrease as high school size increased. Overall, females obtained significantly higher ranks than males. Of further interest is the finding that "a given high school rank will tend to over-predict the achievement of the student from the small school and somewhat underpredict the achievement of the student from larger schools" (p. 572). In summary, Hoyt's study found the following: differences in potential as measured by ACE among students from different size high schools was not significant; first year grades were about the same regardless of school size; males from smaller schools obtained higher ranks than those from larger schools, but the same was not true for females; large sex differences occurred for first year grade point average and high school rank with females obtaining higher averages; no sex differences appeared on ACE; high school rank predicted college grades equally well for students from small or large high schools.

In a later study, Baird (1969) performed a two-way analysis of variance incorporating four levels of high school size with four levels of community setting to determine the effect on achievement of non-academic achievements, high school grades, and ACT composite test score. Significant effects for size and community setting were found for several of the non-academic variables, with all reflecting greater achievement among

students from small schools. High school grades were affected by high school size, community setting, and interactions, with students from rural and small towns obtaining higher grades. But, these same students obtained lower ACT composite test scores.

Downey (1978) studied three groups of Kansas State University students (N = 1932) by dividing them into seven groups based on high school size. He found no support for the hypothesis that students from smaller schools are in some way academically disadvantaged when compared to those from larger schools. Most differences between the groups was in participation in non-academic and extracurricular activities, where students from smaller schools participated more in such pursuits.

A study by Lins, Abell, and Hutchins (1966) compared correlations of the ACT and SAT to total first semester grade point average. While this was not a placement study, but was rather a selection study, some of the results are of interest here. After finding higher first semester GPAs for students who reported SAT scores, the researchers concluded that there was a resident vs. non-resident bias operating, perhaps due to the fact that non-residents were subject to stricter admissions requirements than residents. At the same time, they found little relationship between high school graduating class size and first semester college GPA. The best single correlation with first semester GPA was obtained by using the composite ACT score (0.522 for males, 0.532 for females). Only small increases in correlations were found when multiple regression was applied to include high school centile rank and first semester GPA for males (0.59) and high school centile rank, reading vocabulary, and high school natural science grade for females (0.65). When prediction is of such a global nature, significantly high correlations are difficult to obtain.

Evidently, there is a lack of correlational studies comparing the ability of specific mathematics placement tests and other measures (e. g. SAT, ACT, or high school grade point average) to predict specific college mathematics course grades. Most of the studies found deal with global predictions, and those which are limited to differential prediction tend to concentrate on the ACT or SAT as predictors rather than more custom-made mathematics placement tests. This may account for the small correlations usually found in such studies. As stated by Peters and Plog (1961),

> . . . the more closely a test is designed to fit a particular purpose and to meet the particular conditions under which it is to be used, the less error [in placement decisions] is likely to accrue. (p. 252)

4. SEX DIFFERENCES IN MATHEMATICS ACHIEVEMENT

In an eight-year correlational study using as predictors high school GPA and SAT verbal and mathematics scores, Larson (1976) found high correlations with college GPA. However, including SAT scores for females actually lowered the correlation in some cases, while it improved prediction for males.

Similar sex differences in predictors were found by Siegelman (1971). All subjects were interested in teaching and were in the liberal arts or fine arts, so generalizing to the overall population of college students may not be valid. Correlations of GPA to SAT verbal and mathematics scores and to high school average were higher among females than males, perhaps because there were more females than males in the study group. But, the correlation of high school average to GPA was highest overall for both males and females.

The variable of sex is often overlooked in most studies of the type mentioned above, even though sex differences in mathematics performance have been found. Tsai and Walberg (1983) studied achievement test scores of a sample of participants in the 1977-78 National Association of Educational Progress, and showed that achievement in mathematics was significantly related to sex and favored females, while the difference in attitude toward mathematics was not significant, even though males were favored. Badger (1981) found no significant differences in performance based on sex up until adolescence, at which time males began to out-perform females. The major differences were in spatial ability and judgment. However, Badger goes on to say that affective influences may be a factor in this trend, since females apparently have less confidence than males in their mathematical ability and so tend to take less mathematics:

> The body of research seems to indicate that girls' relatively poor performance in mathematics is linked to broader social attitudes that are particularly powerful at adolescence. (p. 22)

Regardless of the causes of sex differences in mathematics achievement, the fact of their existence suggests that different treatment might be necessary for males and females when placement decisions are to be made. This is justified by the fact that females tend not to do as well as males on many standardized tests, while they do get better grades in college mathematics courses than males.

In a study by Benbow and Stanley (1982), sex differences in mathematics achievement did not appear to be a result of differential course taking by males and females. Differences in mathematical reasoning ability were found before differences in courses taken began to occur. However, Pallas

and Alexander (1983) point out several problems with the Benbow study. They claim that the evidence presented to disclaim the differential coursework hypothesis is indirect evidence since subjects had similar coursework; to test the hypothesis subjects should have had different coursework. Further, the Benbow sample was selected from a high ability group and was not representative of all ability or achievement levels, which affects the generalizability of results. Similar differences in achievement when more heterogeneous groups are used have not been found by other researchers, according to Pallas and Alexander. In their study, students from 24 public schools in 15 communities across the United States were tested in grades five, seven, nine, eleven, and twelve, using the School and College Ability Test (SCAT), and the SAT. No significant difference between males and females was found on the SCAT quantitative test; the largest difference occurred on the SAT mathematics test, favoring males over females. Pallas and Alexander note that females tend to take fewer high level math and science courses than males do, while still obtaining higher grades than males in the common courses they do take. This study offers support for the differential coursework hypothesis.

Do these sex differences carry over into college level mathematics? Decore (1984) found that females at the University of Alberta tended to receive higher grades than males, except in Law and Pharmacy, where differences were not significant. A common explanation for this phenomenon is the selection theory, which maintains that females in college are a select group and should out-perform males which are a more heterogeneous group. However, in the Decore study, the advantage females enjoyed over males remained stable even as female enrollments in the fields where differences

occurred increased. Females continued to fail less frequently than did males. Where it would seem according to the selection theory that differences should dwindle or even disappear as female enrollments approach male enrollments, this was not the case in the Decore study.

Much of the sex difference research agrees that other variables besides sex work in combination to account for the differences in mathematics achievement between males and females, with socioeconomic background, school quality, region of the country or state, or general cognitive ability accounting for much of the variance. Boli, Allen, and Payne (1985) found only small differences in ability and achievement, even when taking into account the different number of courses taken by males and females. Differences appeared to lie in the affective domain, how the different sexes feel about mathematics ability or achievement.

CHAPTER 3

METHODS AND PROCEDURES

1. THE PLACEMENT EXAMS

Each subject was given the two mathematics placement exams published by the Mathematical Association of America. These exams were in use by the Mathematics Department at the University of Tennessee, Knoxville (UTK) for placement in freshman mathematics. The testing took place during two class periods; one exam was administered each day. Each placement test was a twenty-five item multiple choice exam and students were allowed twenty-five minutes to complete each.

Topics covered by the Advanced Algebra Exam were chosen from intermediate and college algebra. The Calculus Readiness Test was divided into two parts. The first twenty questions emphasized word problems, graph interpretation, and advanced algebra concepts. The last five questions were trigonometry questions. Copies of these two exams are provided in Appendix B.

2. THE EXPERIMENTAL GROUP

The general population from which the subjects in this investigation were chosen consists of college students enrolled in an entry level mathematics course at UTK in 1987-88. The experimental group was selected in the following manner:

1) Four sections each of mathematics 1540, 1550, 1700, and 1840 were

picked at random from among all regular lecture sections of those courses taught during the fall quarter of 1987. Since only two sections of Mathematics 1140 were taught that quarter, both were chosen for participation in the study.

2) One instructor of Mathematics 1700 declined to participate in the study. All other instructors agreed to comply with the request to participate.

3) All students enrolled in the chosen sections were asked to participate in the study. A copy of the consent form appears in Appendix A. An explanation of the purpose of the study was presented to each class. At this point, students were given the option to decline to participate in the study. Surprisingly, many students declined to participate. No attempt was made to determine the reasons for this. Table 1 presents the class sizes and the numbers of students from each section of each course who participated in the study. Unfortunately, the percentages of students who participated in the study were very low.

3. COLLECTION OF DATA

The Placement Tests

Administration of the placement tests took place over a two-day period, with one of the two tests given on each day. All subjects were expected to take both exams, however due to absences, some only took one exam. Refer to Table 1 for the numbers of students in each class who took each exam. Twenty minutes were allowed for taking each of the placement exams on the two testing days.

TABLE 1

SAMPLE SIZES FROM EACH CLASS

COURSE	SECTION	CLASS SIZE	NUMBER OF PARTICIPANTS	
			Advanced Algebra	Calculus Readiness
1140	A	39	19	21
1140	B	39	20	27
1540	A	45	16	14
1540	B	42	11	9
1540	C	43	15	15
1540	D	44	23	33
1550	A	43	15	12
1550	B	64	45	28
1550	C	61	43	48
1550	D	60	34	42
1700	A	64	35	45
1700	B	63	16	13
1700	C	65	40	32
1840	A	80	38	36
1840	B	39	22	28
1840	C	40	12	11
1840	D	39	33	32

Other Data Sources

Other student background information was obtained from the office of Student Data Analysis, UTK. This included the high school from which each subject graduated, the number of credits in high school mathematics courses, mathematics score on the ACT test, and high school grade point average (four point scale).

For students who attended high schools in Tennessee the Tennessee Statistical Abstract (1988) was used to determine whether the high school was located in an urban or rural region; the enrollment of the high school was obtained from the Directory of Tennessee Public Schools Approved Nonpublic and Special State Schools (1986-87). For students who attended high schools outside of Tennessee, principals or guidance counselors were contacted by phone to obtain this information.

4. ANALYSIS OF DATA

The placement exams were machine-scored. A data base was then created which contained the social security number, sex, Advanced Algebra and Calculus Readiness test scores, course number, section number and course grade for each subject. A second data base was created which included the number of credits each student received in high school mathematics, English, natural science, and social studies, composite scores and mathematics subscores on the ACT test, scores on the SAT test, high school name and enrollment, and high school type.

All analysis of data was carried out by the Statistical package SAS®. Descriptive statistics were generated; sample sizes, means, standard deviations, minimums, and maximums were obtained for the total group by sex and for each course by sex.

Intercorrelations among the various variables were calculated. Variables included in the correlational study were the two placement tests (for both the summer orientation and the fall testing), high school mathematics credits, high school grade point average, ACT mathematics test subscore, course grade, success, and posttest score. Not all subjects were measured on all of these variables, so sample sizes for each pair of correlation coefficients were different. The correlations were calculated for the group as a whole and for each course separately. Two prediction equations for each course were calculated using stepwise linear regression in SAS®. By using the procedure STEPWISE, a best set of predictors of grade and success were obtained. This set of predictors was then entered into a general linear model procedure to obtain the regression equations. One set of equations predicted grade and success using the Advanced Algebra test and other variables while the other set predicted grade and success using the Calculus Readiness test and other variables. The criterion for entrance of a variable into the prediction equations was a significance level of 0.15.

Differences between means on independent and dependent variables due to section, sex, and high school type were analyzed by means of a Tukey test. Students who were enrolled in a mathematics course higher than that recommended by their placement test score were given a predicted score of F for fail. Students who were enrolled in a mathematics course at the same or lower level than that recommended by the placement test were given a

predicted score of P for pass. Students who obtained a grade below a C in the course were given an actual outcome rating of 0, unsuccessful. Students who obtained a grade of C or better in the course were given an actual outcome rating of 1, success.

Some subjects who were given the placement test during the summer orientation program repeated the examination for purposes of this experiment. To determine whether the mean score of these subjects differed on the two testings, a paired samples t-test was done. In particular, we wished to find out whether these students obtained higher scores when they were retested. Comparisons were made for both the Advanced Algebra and the Calculus Readiness tests.

5. TERMS AND ABBREVIATIONS USED IN THE STUDY

The following terms and abbreviations are used throughout the study:

1) AAFALL: the group who took the Advanced Algebra test in the fall quarter, 1987;

2) CRFALL: the group who took the Calculus Readiness test in the fall quarter, 1987;

3) AASUMMER: the group who took the Advanced Algebra test in the summer orientation testing, 1987;

4) CRSUMMER: the group who took the Calculus Readiness test in the summer orientation testing, 1987;

5) HSGPA: the high school grade point average as calculated on a four point scale;

6) ACTMATH: the mathematics subscore of the American College Testing (ACT) program examination;

7) MATHCRDT: the number of high school mathematics credits accumulated by a student;

8) GRADE: the grade received by a subject in the college mathematics course taken during the fall quarter of 1987;

9) POSTTEST: the score obtained on the posttest;

10) SUCCESS: a variable defined to equal one if a student obtained a grade of C or better in the college mathematics course and zero otherwise;

11) SEXNUM: a variable defined to equal one for males and zero for females;

12) URBAN/BIG: a high school of more than 1000 students located in an urban area;

13) URBAN/SMALL: a high school of 1000 or fewer students located in an urban area;

14) RURAL/BIG: a high school of more than 1000 students located in a rural area;

13) RURAL/SMALL: a high school of 1000 or fewer students located in a rural area;

14) AADIFF: the difference between the Advanced Algebra scores for the summer and fall testings, calculated as AASUMMER-AAFALL;

15) CRDIFF: the difference between the Calculus Readiness scores for the summer and fall testings, calculated as CRSUMMER-CRFALL.

CHAPTER 4

ANALYSIS OF DATA

1. INTRODUCTION

In this chapter, we present the data collected for the study. Descriptive statistics for the total group, males, and females, are provided. We give the results of a Tukey test which looked for differences between sections of each mathematics course on the several variables studied. Correlation matrices are provided, along with tests of significance for the correlations calculated, for the total group and for individual courses. Prediction equations generated by means of linear regression are also given for each course and for each placement test. These equations use the independent variables to predict course grade. An analysis of course placement vs. actual performance for each placement test is presented. The results of a paired-comparisons T-test to determine the effect of retesting students in the study who had been tested during summer orientation are also presented.

2. DESCRIPTIVE STATISTICS FOR THE EXPERIMENTAL GROUP

Table 2 provides an analysis of the descriptive statistics for the total group and for the female and male groups. Sample sizes, means, standard deviations, minimums, and maximums are presented for the variables

TABLE 2

DESCRIPTIVE STATISTICS FOR TOTAL SAMPLE BY SEX

		N	MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
AAFALL	males	239	24	1	10.0	5.0
	females	190	23	2	10.4	5.0
	total	434	24	1	10.1	5.0
CRFALL	males	247	24	1	10.0	5.2
	females	183	24	1	9.3	5.1
	total	434	24	1	10.1	5.0
AASUMMER	males	24	12	1	6.9	2.9
	females	22	18	2	8.1	3.9
	total	46	18	1	7.5	3.4
CRSUMMER	males	72	24	1	12.1	5.2
	females	78	23	1	10.1	4.6
	total	153	24	1	11.1	5.0
HSGPA	males	266	4	1.3	3.0	0.52
	females	212	4	1.8	3.3	0.47
	total	478	4	1.3	3.1	0.5
ACTMATH	males	230	36	7	21.4	5.3
	females	188	30	4	20.1	5.5
	total	418	36	4	20.8	5.4
MATH CREDITS	males	266	5	0.5	3.59	0.95
	females	209	5	1	3.69	0.87
	total	475	5	0.5	3.63	0.92
COURSE GRADE	males	257	4	0	2.1	1.5
	females	204	4	0	2.4	1.5
	total	465	4	0	2.2	1.5
POSTTEST SCORE	males	188	8	0	4.2	1.6
	females	153	8	0	4.2	1.6
	total	345	8	0	4.2	1.6

AAFALL, CRFALL, AASUMMER, CRSUMMER, HSGPA, ACTMATH, MATHCRDT, GRADE, and POSTTEST.

Some interesting differences are apparent in Table 2. As a total group, significant differences between males and females were found on the variables HSGPA and ACTMATH (Tukey, alpha < 0.05). Females had a slightly higher mean HSGPA than males (3.3 vs. 3.0), while males had a higher ACTMATH score than did females (21.4 vs. 20.1). These results are consistent with the findings of Benbow and Stanley (1982), Pallas and Alexander (1983), and Decore (1984). No other differences reached significance.

Table 3 gives the descriptive statistics for the Mathematics 1140 students. No values are given for AASUMMER or CRSUMMER since no Mathematics 1140 students participated in these tests. Differences between males and females in this group due were not found to be significant (Tukey, alpha = 0.05).

Tables 4 presents the descriptive statistics for the students taking Mathematics 1540. The only significant difference found was that for the variable CRFALL where males scored higher than females.

Table 5 gives the descriptive statistics for Mathematics 1550 by sex. Significant differences between males and females were found on AAFALL, CRSUMMER, and MATH CREDITS (Tukey, alpha < 0.05). Females obtained higher mean scores than males on AAFALL (10.1 vs. 8.4) and on MATH CREDITS (3.7 vs. 3.3). Males obtained higher mean CRSUMMER scores (10.9 vs. 7.7).

Table 6 gives the descriptive statistics for Mathematics 1700 by sex. Significant differences between males and females were found for the mean

TABLE 3

DESCRIPTIVE STATISTICS FOR MATHEMATICS 1140 BY SEX

		N	MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
AAFALL	males	20	14	1	6.1	3.2
	females	17	11	2	5.2	2.3
	total	37	14	1	5.7	2.8
CRFALL	males	25	8	2	4.6	1.9
	females	17	11	1	4.8	2.4
	total	42	11	1	4.7	2.1
HSGPA	males	26	3.8	1.9	2.7	0.5
	females	22	3.7	1.8	2.9	0.5
	total	48	3.8	1.8	2.8	0.5
ACTMATH	males	24	23	10	16.7	4.6
	females	18	19	4	14.1	4.2
	total	42	23	4	15.6	4.6
MATH CREDITS	males	25	4	1	2.8	0.9
	females	21	4	1	2.7	0.9
	total	46	4	1	2.8	0.9
COURSE GRADE	males	26	4	0	2.3	1.4
	females	23	4	0	2.2	1.5
	total	49	4	0	2.2	1.5
POSTTEST SCORE	males	24	7	2	4.5	1.4
	females	19	7	1	4.1	1.5
	total	43	7	1	4.3	1.5

TABLE 4

DESCRIPTIVE STATISTICS FOR MATHEMATICS 1540 BY SEX

		N	MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
AAFALL	males	36	18	1	7.2	3.8
	females	29	15	2	7.2	3.6
	total	65	18	1	7.2	3.7
CRFALL	males	37	16	1	7.3	3.4
	females	32	16	1	5.0	3.2
	total	69	16	1	6.2	3.5
AASUMMER	males	19	12	1	6.6	3.0
	females	14	11	2	6.2	2.6
	total	33	12	1	6.4	2.8
CRSUMMER	males	4	12	4	7.0	3.6
	females	5	17	4	8.4	5.1
	total	9	17	4	7.8	4.3
HSGPA	males	40	3.8	2.1	2.9	0.4
	females	34	3.9	2.2	3.1	0.5
	total	74	3.9	2.1	3.0	0.5
ACTMATH	males	33	30	8	19.0	4.9
	females	32	27	8	18.1	4.7
	total	65	30	8	18.5	4.8
MATH CREDITS	males	40	5	2	3.3	0.8
	females	34	5	2	3.1	0.9
	total	74	5	2	3.19	0.82
COURSE GRADE	males	38	4	0	2.7	1.3
	females	34	4	0	2.2	1.6
	total	72	4	0	2.5	1.4
POSTTEST SCORE	males	28	5	2	3.6	1.1
	females	29	7	0	3.7	1.6
	total	57	7	0	3.6	1.4

TABLE 5

DESCRIPTIVE STATISTICS FOR MATHEMATICS 1550 BY SEX

		N	MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
AAFALL	males	65	22	3	8.4	3.8
	females	69	22	2	10.1	4.3
	total	136	22	2	9.3	4.1
CRFALL	males	63	22	1	8.4	3.4
	females	62	19	2	9.4	4.0
	total	126	22	1	8.9	3.7
AASUMMER	males	3	11	8	9.3	1.5
	females	5	18	10	12.8	3.1
	total	8	18	8	11.5	3.1
CRSUMMER	males	8	18	5	10.9	3.8
	females	27	14	1	7.7	3.6
	total	36	18	1	8.3	3.7
HSGPA	males	75	4	1.3	2.8	0.6
	females	75	4	2.2	3.2	0.4
	total	150	4	1.3	3.0	0.5
ACTMATH	males	60	29	7	19.9	5.1
	females	66	29	5	20.2	5.4
	total	126	29	5	20.1	5.2
MATH CREDITS	males	73	5	0.5	3.3	1.0
	females	74	5	1.5	3.7	0.7
	total	147	5	0.5	3.50	0.88
COURSE GRADE	males	70	4	0	2.5	1.4
	females	72	4	0	2.6	1.4
	total	143	4	0	2.5	1.4
POSTTEST SCORE	males	40	7	0	4.0	1.7
	females	43	7	0	4.3	1.6
	total	84	7	0	4.2	1.7

TABLE 6

DESCRIPTIVE STATISTICS FOR MATHEMATICS 1700 BY SEX

		N	MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
AAFALL	males	51	20	1	9.8	4.1
	females	39	22	4	11.2	4.4
	total	91	22	1	10.4	4.2
CRFALL	males	52	20	2	9.4	3.9
	females	37	24	2	9.7	4.3
	total	90	24	2	9.6	4.0
AASUMMER	males	2	8	5	6.5	2.1
	females	3	14	7	9.3	4.0
	total	5	14	5	8.2	3.4
CRSUMMER	males	29	15	1	8.9	3.2
	females	25	21	3	9.8	4.0
	total	55	21	1	9.4	3.6
HSGPA	males	54	3.8	2.1	3.0	0.5
	females	43	4	2.3	3.3	0.4
	total	97	4	2.1	3.2	0.5
ACTMATH	males	49	29	12	22.2	4.3
	females	39	30	4	21.2	5.3
	total	88	30	4	21.8	4.7
MATH CREDITS	males	56	5	1.5	3.7	0.9
	females	43	5	3	4.1	0.7
	total	99	5	1.5	3.87	0.79
COURSE GRADE	males	56	4	0	1.7	1.5
	females	39	4	0	2.4	1.5
	total	56	4	0	1.7	1.5
POSTTEST SCORE	males	42	8	1	4.5	1.8
	females	29	8	1	4.7	1.7
	total	72	8	1	4.5	1.8

scores HSGPA, MATH CREDITS, and COURSE GRADE, with females obtaining slightly higher means than males in these cases (Tukey, alpha < 0.05).

Table 7 presents the descriptive statistics for the course Mathematics 1840 by sex. A significant difference between males and females was found on only one variable, HSGPA, where females had a higher mean than males (3.6 vs. 3.3, Tukey, alpha < 0.05).

In summary, when studied by course, significant differences in means on several variables between males and females become apparent. Most of these differences appear in the middle level courses, Mathematics 1550 and Mathematics 1700. In Mathematics 1550, females outscored males on AAFALL and high school mathematics credits. In Mathematics 1700, females outscored males on HSGPA, high school mathematics credits, and course grade. For the course Mathematics 1540, males outscored females on the CRFALL test. No significant differences between males and females were found in course Mathematics 1140. Finally, as course level increases, the mean score for each variable except AASUMMER, course grade, and posttest also tends to increase.

The cut-off score for placement into Mathematics 1700 by the Advanced Algebra test was set at 12 for the summer testing, but the five Mathematics 1700 students in our study who took the summer test had a mean score of only 8.2 with a standard deviation of 3.4. In addition, the 91 students enrolled in Mathematics 1700 who took the Advanced Algebra test in the fall had a mean score of only 10.4 with a standard deviation of 4.2. The cut-off score for

TABLE 7

DESCRIPTIVE STATISTICS FOR MATHEMATICS 1840 BY SEX

		N	MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
AAFALL	males	68	24	4	14.3	4.7
	females	36	23	7	15	4.6
	total	105	24	4	14.4	4.7
CRFALL	males	71	24	5	15.2	4.9
	females	35	23	5	14.6	4.7
	total	107	24	5	15.0	4.8
CRSUMMER	males	32	24	8	15.9	4.7
	females	21	23	6	14.1	3.9
	total	53	24	6	15.2	4.4
HSGPA	males	70	4	2.0	3.3	0.4
	females	36	4	3.0	3.6	0.3
	total	106	4	2.0	3.4	0.4
ACTMATH	males	63	36	13	25.1	3.9
	females	31	29	17	24.4	2.9
	total	94	36	24.9	3.6	13
MATH CREDITS	males	71	5	2	4.3	0.6
	females	35	5	3	4.3	0.6
	total	106	5	2	4.28	0.59
COURSE GRADE	males	68	4	0	1.8	1.5
	females	36	4	0	2.2	1.3
	total	105	4	0	1.9	1.4
POSTTEST SCORE	males	55	7	2	4.4	1.4
	females	33	7	1	4.2	1.6
	total	89	7	1	4.3	1.5

placement into Mathematics 1700 by the Calculus Readiness test was set at 5 for the summer testing, and the 55 students in Mathematics 1700 and in our study who took the summer test had a mean of 9.4 with a standard deviation of 3.6 In addition, the 90 students enrolled in Mathematics 1700 who took the Calculus Readiness test in the fall had a mean score of 9.6 with a standard deviation of 4.0. This was well above the score recommended for placement into Mathematics 1700. There appears to be little evidence of consistency of results regarding placement recommendations between the Advanced Algebra and Calculus Readiness tests. This means that it is conceivable that a student could obtain two different placement recommendations, depending on which test he or she took. On the one hand, placement into Mathematics 1700 would be indicated; on the other hand, placement into Mathematics 1700 would be precluded.

The cut-off score for placement into Mathematics 1550 by the Advanced Algebra test was set at 11 for the summer testing, and the eight students enrolled in Mathematics 1550 in our study who took the summer test had a mean score of 11.5 with a standard deviation of 3.1. In addition, the 136 students enrolled in Mathematics 1550 and in our study who took the Advanced Algebra test in the fall had a mean score of 9.3 with a standard deviation of 4.1. The cut-off score for placement into Mathematics 1550 by the Calculus Readiness test was set at 5 for the summer testing and the 36 students enrolled in Mathematics 1550 and in our study who took the summer test had a mean score of 8.3 with a standard deviation of 3.7. In addition, the 126 students enrolled in Mathematics 1550 and in our study who took the Calculus Readiness test in the fall had a mean score of 8.9 with a standard deviation of 3.7. This mean was well above the recommended cut-off score

for placement into Mathematics 1550. Again, it is conceivable that a student could obtain two different placement recommendations depending on which test he or she took.

The cut-off score for placement into Mathematics 1840 by the Calculus Readiness test was set at 12 for the summer testing and the 53 students enrolled in Mathematics 1840 and in our study who took that test had a mean of 15.2 with a standard deviation of 4.4. In addition, the 107 students enrolled in Mathematics 1840 and in our study who took the test in the fall obtained a mean of 15 with a standard deviation of 4.8. The cut-off score for placement into Mathematics 1840 for the Advanced Algebra test was set at 20 for the summer testing. No Mathematics 1840 students in our study took the Advanced Algebra test in the summer. However, the 105 students enrolled in Mathematics 1840 who took the Advanced Algebra test in the fall obtained a mean score of 14.4 with a standard deviation of 4.7. This was well below the score needed for Mathematics 1840 placement based on this test. Once again, two different placement recommendations could result depending on which test a student takes.

Mathematics 1700 and Mathematics 1840 students had lower mean course grades than all other groups. There were significant differences between Mathematics 1840 and Mathematics 1550, and between Mathematics 1700 and Mathematics 1550 (Tukey, alpha < 0.05).

Since each course had a unique posttest, comparisons between courses on posttest scores do not seem appropriate. No significant differences between males and females were found on mean posttest scores.

3. DIFFERENCES BETWEEN SECTIONS

In general, significant differences between sections of a course were found on several variables (Tukey, alpha < 0.05). A summary of the results is presented in Table 8. Different sections of each course are identified by letters to preserve anonymity. Means are given only for those variables for which significant differences were found.

One section of Mathematics 1140 scored better than the other on CRFALL and COURSE GRADE. No significant differences were found between sections of Mathematics 1540. One section of Mathematics 1550 had lower ACTMATH scores than all the others. A second section had lower COURSE GRADES than two others. One section of Mathematics 1700 had higher AAFALL, MATH CREDITS, and POSTTEST score than the others. One section of Mathematics 1840 had lower scores on AAFALL and HSGPA than two others.

These differences may be a result of the non-randomness of our sample, especially since the differences appear to favor one section over others in a consistent manner. Perhaps in the favored sections, those who volunteered for participation were more highly motivated than those in the non-favored sections.

4. CORRELATIONS BETWEEN VARIABLES

Table 9 presents the correlation matrix for the total sample for variables AAFALL, CRFALL, AASUMMER, CRSUMMER, HSGPA, ACTMATH, MATH CREDITS, COURSE GRADE, POSTTEST, and SUCCESS. As seen in Table

TABLE 8

DIFFERENCES BETWEEN SECTIONS
ON VARIABLES

COURSE	SECTION	AAFALL	CRFALL	GRADE	ACTMATH	MATH CREDITS	POSTTEST SCORE
1140	A		6	3.02			
	B		3.9	1.71			
1550	A				18		
	B			2.8	20.38		
	C			2.46	16.71		
	D			2.31	18.08		
1700	A	12.09				4.05	5.86
	B						3.8
	C	9.46				3.6	3.4
1840	A	15.45	16.9				5.25
	B	16.2					4.05
	D	12.24	13.18				3.68

TABLE 9

CORRELATION MATRIX AND SAMPLE SIZES FOR TOTAL SAMPLE

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1 (AAFALL)	--	.77** 343	.70** 34	.60** 121	.42** 382	.61** 343	.55** 380	.26** 369	.31** 288	.19** 369
X_2 (CRFALL)		–	.52** 39	.75** 126	.45** 383	.66** 342	.52** 382	.22** 368	.28** 283	.19** 368
X_3 (AASUMMER)			--	--	.33* 39	.52** 36	.60** 39	.39** 37	.53** 31	.13 37
X_4 (CRSUMMER)				--	.31** 132	.61** 123	.47** 132	.21* 132	.10 104	.24** 132
X_5 (HSGPA)					--	.42** 380	.47** 422	.34** 406	.21** 303	.29** 406
X_6 (ACTMATH)						--	.55** 378	.27** 362	.29** 273	.22** 362
X_7 (MATH CREDITS)							--	.25** 404	.26** 302	.22** 404
X_8 (COURSE GRADE)								--	.33** 304	.87** 408
X_9 (POSTTEST)									–	.27** 304
X_{10} (SUCCESS)										–

*Significant at the 0.05 level.
**Significant at the 0.01 level.

9, correlations between most variables were significant. This suggests that there is much flexibility in the variables that can be chosen for the model. A determining factor in this choice should be convenience. Ignoring the correlations between course grade, success and posttest score, which are to be expected since success is a reflection of course grade and the course grade was affected by posttest score, the best correlates with grade were AASUMMER, HSGPA, ACTMATH, AAFALL, high school mathematics credits, CRFALL, and CRSUMMER. However, these correlations, with R^2 values ranging from 0.15 to 0.04, do not provide much leverage for grade prediction.

If success is used as a criterion instead of course grade, the results are not any better. Ignoring the expected correlation with grade, the variables correlate with success in the order HSGPA, posttest, CRSUMMER, ACTMATH, high school mathematics credits, AAFALL, and CRFALL. The range of R^2 in this case is 0.08 to 0.02. Again this is not very satisfying.

Table 10 is the correlation matrix for course Mathematics 1140 using the variables AAFALL, CRFALL, HSGPA, ACTMATH, MATH CREDITS, COURSE GRADE, POSTTEST, and SUCCESS. Only a few correlations were significant. Again, ignoring the expected correlation between grade, posttest, and success, the best correlate with grade in this group was ACTMATH with an R^2 value of about 0.12. AAFALL was a significant correlate with MATH CREDITS ($R^2 = 0.16$); ACTMATH was significantly correlated with POSTTEST SCORE, MATH CREDITS, and COURSE GRADE, with R^2 in the range of 0.31 to 0.12. Finally, MATH CREDITS were significantly correlated with POSTTEST SCORE ($R^2 = 0.13$). Once again, for purposes of predicting grades, these values of R^2 do not provide much leverage.

TABLE 10

CORRELATION MATRIX AND SAMPLE SIZES
FOR MATHEMATICS 1140

	X_1	X_2	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1 (AAFALL)	--	.12 30	-.01 34	.12 30	.40* 33	.15 34	.11 32	.15 34
X_2 (CRFALL)		–	.9 38	-.01 34	<0 38	.12 38	-.25 36	.03 38
X_5 (HSGPA)			--	.05 38	.23 43	.24 44	.11 39	.26 44
X_6 (ACTMATH)				--	.49** 38	.34* 38	.56** 34	.24 38
X_7 (MATH CREDITS)					--	.16 43	.36* 38	.22 43
X_8 (COURSE GRADE)						--	.42** 39	.84** 44
X_9 (POSTTEST)							–	.34* 39
X_{10} (SUCCESS)								–

*Significant at the 0.05 level.
**Significant at the 0.01 level.

Table 11 gives the correlations for Mathematics 1540 for AAFALL, CRFALL, AASUMMER, CRSUMMER, HSGPA, ACTMATH, MATH CREDITS, COURSE GRADE, POSTTEST, and SUCCESS. In Mathematics 1540, the best correlate among the independent variables with grade was high school mathematics credits ($R^2 = 0.35$). HSGPA was the second best correlate with course grade ($R^2 = 0.26$), and ACTMATH score was third ($R^2 = 0.24$). Both HSGPA and ACTMATH had equal correlations with success, but accounted for much less variance than they did in course grade ($R^2 = 0.18$). Sample size for the CRSUMMER test was so small that the correlation with course grade is not very meaningful. The AAFALL and AASUMMER placement tests were more highly correlated with course grade in Mathematics 1540 than the CRFALL test. But the Advanced Algebra tests still accounted for only about 20% of the variance in grade compared to about 11% for the CRFALL test.

As seen in Table 12, in Mathematics 1550 the best correlate with grade among the independent variables was HSGPA ($R^2 = 0.14$). CRFALL and HSGPA correlated equally well with success ($R^2 = 0.08$). Both placement tests AAFALL and CRFALL correlated equally well with course grade, but accounted for only slightly over 12% of the variance in grade. This was better than the results obtained by using correlation with success ($R^2 = 0.04$ for AAFALL, $R^2 = 0.08$ for CRFALL). The sample size for the AASUMMER group in Mathematics 1550 was too small to make any conclusions. In general, although significant intercorrelations were present among independent variables, the tendency toward small values of R^2 persists in Mathematics 1550.

TABLE 11

CORRELATION MATRIX AND SAMPLE SIZES FOR MATHEMATICS 1540

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1 (AAFALL)	--	.53** 56	.28 25	.49 9	.23* 59	.44** 52	.50** 59	.43** 57	.40** 45	.24 57
X_2 (CRFALL)		–	.33 28	.91** 4	.23 63	.55** 55	.35** 63	.33** 62	.18 50	.18 62
X_3 (AASUMMER)			–	–	.29 28	.47* 27	.49** 28	.45* 27	.50* 25	.9 27
X_4 (CRSUMMER)				–	.34 9	.67 8	.27 9	.51 9	.35 7	.49 9
X_5 (HSGPA)					--	.20 59	.40** 67	.51** 65	.28* 52	.42** 65
X_6 (ACTMATH)						--	.35** 59	.49** 57	.19 46	.42** 57
X_7 (MATH CREDITS)							--	.59** 65	.46** 52	.40** 65
X_8 (COURSE GRADE)								--	.58** 52	.87** 65
X_9 (POSTTEST)									–	.43** 52
X_{10} (SUCCESS)										–

*Significant at the 0.05 level.
**Significant at the 0.01 level.

TABLE 12

CORRELATION MATRIX AND SAMPLE SIZES
FOR MATHEMATICS 1550

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1 (AAFALL)	--	.73**	.92*	.11	.36**	.48**	.47**	.35**	.40**	.20*
		97	5	28	119	103	117	115	71	115
X_2 (CRFALL)		–	38	.20	.44**	.54**	.39**	.35**	.47**	.29**
			6	28	110	95	109	105	60	105
X_3 (AASUMMER)			–	–	.63	.82	.55	.7	1	.14
					6	5	6	6	2	6
X_4 (CRSUMMER)				–	.24	.01	.18	-.01	-.18	-.02
					31	30	31	31	19	31
X_5 (HSGPA)					--	.34**	.39**	.38**	.32**	.29**
						114	130	125	71	125
X_6 (ACTMATH)						--	.40**	.33**	.46**	.27**
							113	109	62	109
X_7 (MATH CREDITS)							--	.34**	.20*	.28**
								123	70	123
X_8 (COURSE GRADE)								--	.39**	.84**
									71	125
X_9 (POSTTEST)									–	.23
										71
X_{10} (SUCCESS)										–

*Significant at the 0.05 level.
**Significant at the 0.01 level.

Tables 13 and 14 give the correlations and sample sizes for Mathematics 1700 and Mathematics 1840, respectively. In Mathematics 1700, the best correlate with grade among the independent variables was HSGPA ($R^2 = 0.32$). The best correlate with success was also HSGPA ($R^2 = 0.28$). The sample size for AASUMMER was too small to consider the correlation of 0.53 meaningful. Both placement tests in the fall were highly correlated with course grade, accounting for about 30% of the variance in grade. Again, significant intercorrelations were found among the many independent variables.

In Mathematics 1840, the best correlate with grade among the independent variables was CRSUMMER ($R^2 = 0.35$), and CRSUMMER also correlated best with success ($R^2 = 0.26$). Refer to Table 14. The next best correlate with grade was AAFALL, accounting for about 34% of the variance in grade. ACTMATH score was also a good correlate with grade ($R^2 = 0.32$). Intercorrelations among independent variables were again plentiful and significant.

In general, correlations among the many independent variables were high and significant. This suggests that much latitude exists in the choice of variables to be used as predictors of grades or success. The choice can thus be made based on convenience. The percentage of variance accounted for in both grades and success by individual variables was generally low, even though correlations were high and significant. This suggests that a better model for predicting grades or success would result if several predictors were used in regression equations.

TABLE 13

CORRELATION MATRIX AND SAMPLE SIZES
FOR MATHEMATICS 1700

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1 (AAFALL)	--	.65** 71	.63 4	.54** 42	.39** 79	.45** 72	.38** 80	.53** 76	.37** 62	.40** 76
X_2 (CRFALL)		–	.45 5	.59** 45	.32** 79	.54** 71	.41** 79	.56** 75	.30* 57	.44** 75
X_3 (AASUMMER)			–	–	.43 5	-.64 4	.95* 5	.53 4	.17 4	.95 4
X_4 (CRSUMMER)				–	.34* 47	.58** 42	.35* 47	.45** 47	.16 37	.30* 47
X_5 (HSGPA)					--	.35** 79	.35** 87	.57** 82	.98 61	.53** 82
X_6 (ACTMATH)						--	.36** 79	.36** 74	.11 55	.19 74
X_7 (MATH CREDITS)							--	.40** 83	.30* 62	.34** 83
X_8 (COURSE GRADE)								--	.28* 62	.90** 83
X_9 (POSTTEST)									–	.37** 62
X_{10} (SUCCESS)										–

*Significant at the 0.05 level.
**Significant at the 0.01 level.

TABLE 14

CORRELATION MATRIX AND SAMPLE SIZES
FOR MATHEMATICS 1840

	X_1	X_2	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1 (AAFALL)	--	.67** 89	.55** 42	.18 91	.58** 86	.20 91	.58** 87	.36** 78	.49** 87
X_2 (CRFALL)		–	.78** 44	.18 93	.59** 87	.25* 93	.53** 88	.41** 80	.45** 88
X_4 (CRSUMMER)			–	.22 45	.65** 43	.35* 45	.59** 45	.21 41	.51** 45
X_5 (HSGPA)				--	.26* 90	.22* 95	.38** 90	.28* 80	.31** 90
X_6 (ACTMATH)					--	.24* 89	.57** 84	.25* 76	.47** 84
X_7 (MATH CREDITS)						--	.37** 90	.09 80	.38** 90
X_8 (COURSE GRADE)							--	.32** 80	.88** 91
X_9 (POSTTEST)								–	.26* 80
X_{10} (SUCCESS)									–

*Significant at the 0.05 level.
**Significant at the 0.01 level.

5. PREDICTION EQUATIONS

For each placement test prediction equations for each course were obtained by stepwise linear regression using that placement test score along with other variables. The entrance criterion for inclusion of a variable in the regression was a significance level of 0.15. Variables considered for possible inclusion were AAFALL, CRFALL, HSGPA, ACTMATH, high school mathematics credits, and sex. The amount of variance accounted for by these variables when SUCCESS was the criterion was smaller over all courses than that accounted for when COURSE GRADE was the criterion. Since the correlation between these two criteria was high over all courses, the COURSE GRADE was used as the criterion in the prediction equations.

Table 15 provides the stepwise prediction equations for Mathematics 1140 using the Advanced Algebra test. The F-value for each equation is given as are the partial and total R^2 values. The prediction equation for course Mathematics 1140 using the Advanced Algebra test accounts for almost 22% of the variance in grade and depends on HSGPA (X_5) and ACTMATH score (X_6). Table 16 presents B-coefficients and standard error for prediction equations for Mathematics 1140 using the Advanced Algebra test.

Table 17 provides the stepwise prediction equations for Mathematics 1140 using the Calculus Readiness test. The F-value for each equation is given as are the partial and total R^2 values. The prediction equation for course Mathematics 1140 using the Calculus Readiness test accounts for almost 23% of the variance in grade and depends on HSGPA (X_5) and ACTMATH score (X_6). Table 18 presents B-coefficients and standard error for prediction equations for Mathematics 1140 using the Calculus Readiness test.

TABLE 15

PREDICTION EQUATIONS FOR MATHEMATICS 1140:
PREDICTING GRADE WITH ADVANCED ALGEBRA TEST

STEP	EQUATION	F	PARTIAL R^2	TOTAL R^2
1	$Y_1 = 0.5 + 0.11X_6$	4.09	0.1236	0.1236
2	$Y_1 = -2.45 + 0.98X_5 + 0.12X_6$	3.92*	0.0951	0.2187

*Significant at the 0.05 level.

TABLE 16

COEFFICIENTS AND STANDARD ERROR FOR
PREDICTION EQUATION FOR MATHEMATICS 1140:
PREDICTING GRADE WITH ADVANCED ALGEBRA TEST

COEFFICIENT	STANDARD ERROR	F VALUE	PR > F
0.9823 (X_5)	0.5321	3.41	0.0755
0.1169 (X_6)	0.0539	4.70	0.0388

TABLE 17

PREDICTION EQUATIONS FOR MATHEMATICS 1140:
PREDICTING GRADE WITH CALCULUS READINESS TEST

STEP	EQUATION	F	PARTIAL R^2	TOTAL R^2
1	$Y_1 = -0.85 + 1.08X_5$	5.43*	0.1344	0.1344
2	$Y_1 = -2.20 + 1.02X_5 + 0.095X_6$	4.99*	0.0926	0.2270

*Significant at the 0.05 level.

TABLE 18

COEFFICIENTS AND STANDARD ERROR FOR
PREDICTION EQUATION FOR MATHEMATICS 1140:
PREDICTING GRADE WITH CALCULUS READINESS TEST

COEFFICIENT	STANDARD ERROR	F VALUE	PR > F
1.0232 (X_5)	0.4437	5.32	0.0273
0.0948 (X_6)	0.0470	4.07	0.0515

Table 19 provides the stepwise prediction equations for Mathematics 1540 using the Advanced Algebra test. The F-value for each equation is given as are the partial and total R^2 values. The prediction equation for course Mathematics 1540 using the Advanced Algebra test accounts for over 46% of the variance in grade and depends on HSGPA (X_5), ACTMATH score (X_6), and high school mathematics credits (X_7). Table 20 presents B-coefficients and standard error for prediction equations for Mathematics 1540 using the Advanced Algebra test.

Table 21 provides the stepwise prediction equations for Mathematics 1540 using the Calculus Readiness test. The F-value for each equation is given as are the partial and total R^2 values. The prediction equation for course Mathematics 1540 using the Calculus Readiness test accounts for almost 50% of the variance in grade and depends on HSGPA (X_5), ACTMATH score (X_6), and high school mathematics credits (X_7). Table 22 presents B-coefficients and standard error for prediction equations for Mathematics 1540 using the Calculus Readiness test.

Table 23 provides the stepwise prediction equations for Mathematics 1550 using the Advanced Algebra test. The F-value for each equation is given as are the partial and total R^2 values. The prediction equation for course Mathematics 1550 using the Advanced Algebra test accounts for almost 31% of the variance in grade and depends on AAFALL (X_1), HSGPA (X_5), high school mathematics credits (X_7), and sex (X_{11}). Table 24 presents B-coefficients and standard error for prediction equations for Mathematics 1550 using the Advanced Algebra test.

TABLE 19

PREDICTION EQUATIONS FOR MATHEMATICS 1540:
PREDICTING GRADE WITH ADVANCED ALGEBRA TEST

STEP	EQUATION	F	PARTIAL R^2	TOTAL R^2
1	$Y_1 = -0.52 + 0.96X_7$	20.92**	0.2830	0.2830
2	$Y_1 = -3.00 + 1.03X_5 + 0.75X_7$	16.39**	0.1037	0.3867
3	$Y_1 = -3.96 + 0.91X_5 + 0.09X_6 + 0.63X_7$	14.71**	0.0772	0.4638

**Significant at the 0.01 level.

TABLE 20

COEFFICIENTS AND STANDARD ERROR FOR
PREDICTION EQUATION FOR MATHEMATICS 1540:
PREDICTING GRADE WITH ADVANCED ALGEBRA TEST

COEFFICIENT	STANDARD ERROR	F VALUE	PR > F
0.9116 (X_5)	0.3298	7.64	0.0079
0.0894 (X_6)	0.0330	7.34	0.0092
0.6253 (X_7)	0.2009	9.69	0.0030

TABLE 21

PREDICTION EQUATIONS FOR MATHEMATICS 1540:
PREDICTING GRADE WITH CALCULUS READINESS TEST

STEP	EQUATION	F	PARTIAL R^2	TOTAL R^2
1	$Y_1 = -0.92 + 1.076X_7$	30.89**	0.3514	0.3514
2	$Y_1 = -2.34 + 0.10X_6 + 0.92X_7$	21.66**	0.0847	0.4362
3	$Y_1 = -4.36 + 0.86X_5 + 0.09X_6 + 0.79X_7$	18.27**	0.0629	0.4991

**Significant at the 0.01 level.

TABLE 22

COEFFICIENTS AND STANDARD ERROR FOR
PREDICTION EQUATION FOR MATHEMATICS 1540:
PREDICTING GRADE WITH CALCULUS READINESS TEST

COEFFICIENT	STANDARD ERROR	F VALUE	PR > F
0.8577 (X_5)	0.3263	6.91	0.0111
0.0925 (X_6)	0.0331	7.78	0.0073
0.7856 (X_7)	0.1867	17.71	0.0001

TABLE 23

PREDICTION EQUATIONS FOR MATHEMATICS 1550:
PREDICTING GRADE WITH ADVANCED ALGEBRA TEST

STEP	EQUATION	F	PARTIAL R^2	TOTAL R^2
1	$Y_1 = -1.57 + 1.30X_5$	26.15**	0.1964	0.1964
2	$Y_1 = -2.53 + 0.99X_5 + 0.53X_7$	18.40**	0.0613	0.2577
3	$Y_1 = -2.33 + 0.07X_1 + 0.86X_5 + 0.41X_7$	13.98**	0.0277	0.2854
4	$Y_1 = -3.00 + 0.08X_1 + 0.99X_5 + 0.40X_7 + 0.46X_{11}$	11.56**	0.0223	0.3077

**Significant at the 0.01 level.

TABLE 24

COEFFICIENTS AND STANDARD ERROR FOR
PREDICTION EQUATION FOR MATHEMATICS 1550:
PREDICTING GRADE WITH ADVANCED ALGEBRA TEST

COEFFICIENT	STANDARD ERROR	F VALUE	PR > F
0.0761 (X_1)	0.0332	5.24	0.0241
0.9932 (X_5)	0.2778	12.79	0.0005
0.4032 (X_7)	0.1851	4.75	0.0316
0.4621 (X_{11})	0.2522	3.36	0.0698

Table 25 provides the stepwise prediction equations for Mathematics 1550 using the Calculus Readiness test. The F-value for each equation is given as are the partial and total R^2 values. The prediction equation for course Mathematics 1550 using the Calculus Readiness test accounts for almost 28% of the variance in grade and depends on HSGPA (X_5) and high school mathematics credits (X_7). Table 26 presents B-coefficients and standard error for prediction equations for Mathematics 1550 using the Calculus Readiness test.

Table 27 provides the stepwise prediction equations for Mathematics 1700 using the Advanced Algebra test. The F-value for each equation is given as are the partial and total R^2 values. The prediction equation for course Mathematics 1700 using the Advanced Algebra test accounts for over 52% of the variance in grade and depends on AAFALL (X_1), HSGPA (X_5) and high school mathematics credits (X_7). Table 28 presents B-coefficients and standard error for prediction equations for Mathematics 1700 using the Advanced Algebra test.

Table 29 provides the stepwise prediction equations for Mathematics 1700 using the Calculus Readiness test. The F-value for each equation is given as are the partial and total R^2 values. The prediction equation for course Mathematics 1700 using the Calculus Readiness test accounts for almost 52% of the variance in grade and depends on CRFALL (X_2), HSGPA (X_5) and high school mathematics credits (X_7). Table 30 presents B-coefficients and standard error for prediction equations for Mathematics 1700 using the Calculus Readiness test.

TABLE 25

PREDICTION EQUATIONS FOR MATHEMATICS 1550:
PREDICTING GRADE WITH CALCULUS READINESS TEST

STEP	EQUATION	F	PARTIAL R^2	TOTAL R^2
1	$Y_1 = -0.26 + 0.82X_7$	26.64**	0.2172	0.2172
2	$Y_1 = -1.97 + 0.77X_5 + 0.63X_7$	18.25**	0.0603	0.2775

**Significant at the 0.01 level.

TABLE 26

COEFFICIENTS AND STANDARD ERROR FOR
PREDICTION EQUATION FOR MATHEMATICS 1550:
PREDICTING GRADE WITH CALCULUS READINESS TEST

COEFFICIENT	STANDARD ERROR	F VALUE	PR > F
0.7662 (X_5)	0.2721	7.93	0.0059
0.6332 (X_7)	0.1684	14.13	0.0003

TABLE 27

PREDICTION EQUATIONS FOR MATHEMATICS 1700:
PREDICTING GRADE WITH ADVANCED ALGEBRA TEST

STEP	EQUATION	F	PARTIAL R^2	TOTAL R^2
1	$Y_1 = -4.17 + 1.92X_5$	37.82**	0.3413	0.3413
2	$Y_1 = -4.18 + 0.12X_1 + 1.51X_5$	30.96**	0.1211	0.4623
3	$Y_1 = -5.20 + 0.10X_1 + 1.20X_5 + 0.56X_7$	25.78**	0.0590	0.5216

**Significant at the 0.01 level.

TABLE 28

COEFFICIENTS AND STANDARD ERROR FOR
PREDICTION EQUATION FOR MATHEMATICS 1700:
PREDICTING GRADE WITH ADVANCED ALGEBRA TEST

COEFFICIENT	STANDARD ERROR	F VALUE	PR > F
0.1003 (X_1)	0.0298	11.30	0.0013
1.2019 (X_5)	0.3047	15.56	0.0002
0.5630 (X_7)	0.1903	8.75	0.0042

TABLE 29

PREDICTION EQUATIONS FOR MATHEMATICS 1700:
PREDICTING GRADE WITH CALCULUS READINESS TEST

STEP	EQUATION	F	PARTIAL R^2	TOTAL R^2
1	$Y_1 = -2.43 + 1.11X_7$	30.41**	0.2941	0.2941
2	$Y_1 = -2.83 + 0.15X_2 + 0.84X_7$	28.02**	0.1436	0.4376
3	$Y_1 = -5.13 + 0.14X_2 + 1.04X_5 + 0.60X_7$	25.44**	0.0804	0.5181

**Significant at the 0.01 level.

TABLE 30

COEFFICIENTS AND STANDARD ERROR FOR
PREDICTION EQUATION FOR MATHEMATICS 1700:
PREDICTING GRADE WITH CALCULUS READINESS TEST

COEFFICIENT	STANDARD ERROR	F VALUE	PR > F
0.1366 (X_2)	0.0331	17.07	0.0001
1.0444 (X_5)	0.3034	11.85	0.0010
0.6048 (X_7)	0.1917	9.96	0.0024

Table 31 provides the stepwise prediction equations for Mathematics 1840 using the Advanced Algebra test. The F-value for each equation is given as are the partial and total R^2 values. The prediction equation for course Mathematics 1840 using the Advanced Algebra test accounts for almost 49% of the variance in grade and depends on AAFALL(X_1), HSGPA (X_5), ACTMATH score (X_6), and high school mathematics credits (X_7). Table 32 presents B-coefficients and standard error for prediction equations for Mathematics 1840 using the Advanced Algebra test.

Table 33 provides the stepwise prediction equations for Mathematics 1840 using the Calculus Readiness test. The F-value for each equation is given as are the partial and total R^2 values. The prediction equation for course Mathematics 1840 using the Calculus Readiness test accounts for almost 54% of the variance in grade and depends on CRFALL (X_2), HSGPA (X_5), ACTMATH score (X_6), high school mathematics credits (X_7), and sex (X_{11}). Table 34 presents B-coefficients and standard error for prediction equations for Mathematics 1840 using the Calculus Readiness test.

Several observations are worthy of note at this time. Neither placement test was a factor in the prediction equations for the courses Mathematics 1140 or Mathematics 1540. For Mathematics 1550, the Calculus Readiness test did not appear in the prediction equation. In Mathematics 1700, prediction equations with the Advanced Algebra test and the Calculus Readiness test accounted for the same amount of variance in grade. In Mathematics 1840, better results are obtained with the Calculus Readiness test, but sex is also a factor. Perhaps the most interesting observation is that we can still only account for 54% of the variance in grade with even our best prediction equation.

TABLE 31

PREDICTION EQUATIONS FOR MATHEMATICS 1840:
PREDICTING GRADE WITH ADVANCED ALGEBRA TEST

STEP	EQUATION	F	PARTIAL R^2	TOTAL R^2
1	$Y_1 = -0.76 + 0.18X_1$	47.12**	0.3678	0.3678
2	$Y_1 = -3.79 + 0.17X_1 + 0.92X_5$	30.17**	0.0622	0.4300
3	$Y_1 = -4.99 + 0.13X_1 + 0.81X_5 + 0.09X_6$	22.65**	0.0324	0.4624
4	$Y_1 = -6.26 + 0.13X_1 + 0.74X_5 + 0.08X_6 + 0.41X_7$	18.49**	0.0243	0.4867

**Significant at the 0.01 level.

TABLE 32

COEFFICIENTS AND STANDARD ERROR FOR
PREDICTION EQUATION FOR MATHEMATICS 1840:
PREDICTING GRADE WITH ADVANCED ALGEBRA TEST

COEFFICIENT	STANDARD ERROR	F VALUE	PR > F
0.1266 (X_1)	0.0296	18.26	0.0001
0.7427 (X_5)	0.3063	5.88	0.0176
0.0782 (X_6)	0.0387	4.09	0.0466
0.4133 (X_7)	0.2150	3.70	0.0582

TABLE 33

PREDICTION EQUATIONS FOR MATHEMATICS 1840:
PREDICTING GRADE WITH CALCULUS READINESS TEST

STEP	EQUATION	F	PARTIAL R^2	TOTAL R^2
1	$Y_1 = -0.81 + 0.18X_2$	46.06**	0.3654	0.3654
2	$Y_1 = -4.59 + 0.16X_2 + 1.15X_5$	33.68**	0.0949	0.4602
3	$Y_1 = -6.50 + 0.15X_2 + 1.03X_5 + 0.58X_7$	26.41**	0.0436	0.5039
4	$Y_1 = -7.29 + 0.12X_2 + 0.92X_5 + 0.07X_6 + 0.54X_7$	21.30**	0.0215	0.5253
5	$Y_1 = -6.71 + 0.12X_2 + 0.80X_5 + 0.08X_6 + 0.51X_7 - 0.37X_{11}$	17.80**	0.0141	0.5394

**Significant at the 0.01 level.

TABLE 34

COEFFICIENTS AND STANDARD ERROR FOR
PREDICTION EQUATION FOR MATHEMATICS 1840:
PREDICTING GRADE WITH CALCULUS READINESS TEST

COEFFICIENT	STANDARD ERROR	F VALUE	PR > F
0.1203 (X_2)	0.0293	16.89	0.0001
0.8022 (X_5)	0.3093	6.73	0.0114
0.0810 (X_6)	0.0397	4.16	0.0448
0.5111 (X_7)	0.2191	5.44	0.0223
-0.3712 (X_{11})	0.2433	2.33	0.1311

6. ANALYSIS OF COURSE PLACEMENT VS. ACTUAL PERFORMANCE

Using the same cut-off points for the AAFALL and CRFALL tests as were used in the summer testing, a prediction of either passing or failing performance was made for each subject. Passing performance was predicted for a student enrolled in a course at the same or lower level than the placement test score indicated to be appropriate. Failing performance was predicted for a student enrolled in a course at a higher level than the one indicated by the placement test score. The actual outcome as represented by course grade was either a fail (grade of D or F) or a pass (grade of C or better).

Figures 2 and 3 present the analysis of mathematics course placement for the total group and by sex using the Advanced Algebra test. As seen in Figure 2, among those predicted to pass by this placement test, over 85% actually passed, while among those predicted to fail, almost 62% were able to pass. For females the probability of passing when predicted to pass was 86%, while for males this probability was 84%; but a large percentage of both males and females who passed was predicted to fail (about 60%). As seen in Figure 3, among those students who failed almost 40% were predicted to pass and 15% were predicted to fail. For both females and males the probability of failing when predicted to pass was just over 10%, and that of failing when predicted to fail was nearly 40%. These results indicate that the Advanced Algebra test tended to overpredict failure in general.

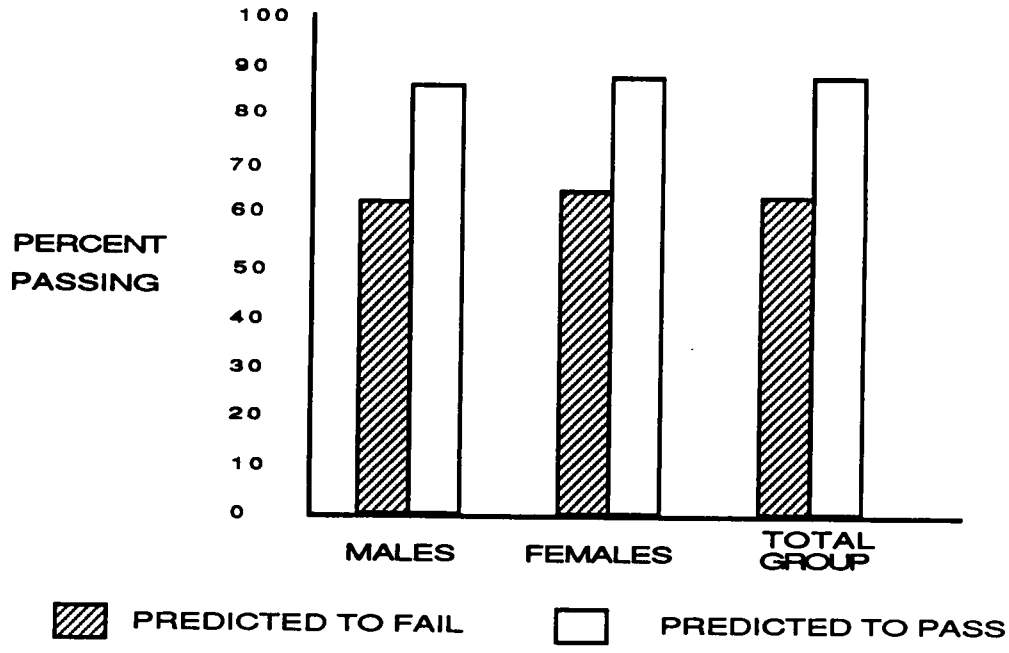


FIGURE 2: ANALYSIS OF MATHEMATICS COURSE PLACEMENT FOR TOTAL GROUP BY SEX WITH ADVANCED ALGEBRA TEST: PERCENT PASSING

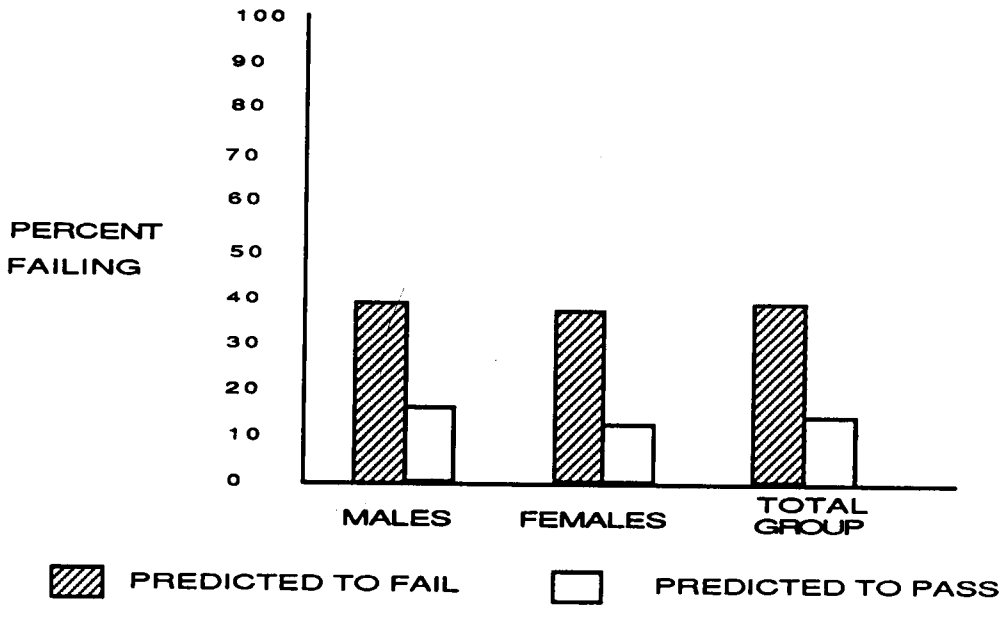


FIGURE 3: ANALYSIS OF MATHEMATICS COURSE PLACEMENT FOR TOTAL GROUP BY SEX WITH ADVANCED ALGEBRA TEST: PERCENT FAILING

Figures 4 and 5 present the analysis of mathematics course placement for the total group and by sex using the Calculus Readiness test. As seen in Figure 4, among those predicted to pass by this placement test, about 73% actually passed, while among those predicted to fail, 40% were able to pass. For females the probability of passing when predicted to pass was 75%, while for males this probability was 72%; a large percentage of females who passed was predicted to fail (57%), while a much smaller percentage of males who passed was predicted to fail (26%). As seen in Figure 5, among those students who failed only 27% were predicted to pass while 61% were predicted to fail. For females the probability of failing when predicted to pass was 25%, and that of failing when predicted to fail was 43%. The corresponding figures for males were 28% and 74%. Evidently, females were able to pass their mathematics courses in spite of low placement test scores on the Calculus Readiness more readily than males were.

Figures 6 and 7 present the analysis of mathematics course placement by course using the Advanced Algebra test. For Mathematics 1140, Figure 6 shows that the probability of passing when predicted to pass is about the same as that of passing when predicted to fail, while Figure 7 indicates that the probability of failing when predicted to fail is about the same as that of passing when predicted to fail. Thus it appears that the Advanced Algebra test is not useful for Mathematics 1140 placement. Similarly, for Mathematics 1540, Figure 6 indicates that only about thirteen percentage points separate the predicted passing and failing students in the group of students who passed; the same is true among students who failed (Figure 7). The results are only slightly better for Mathematics 1550 students. Figure 6 shows that 94% of those predicted to pass actually passed, while 72% of those predicted

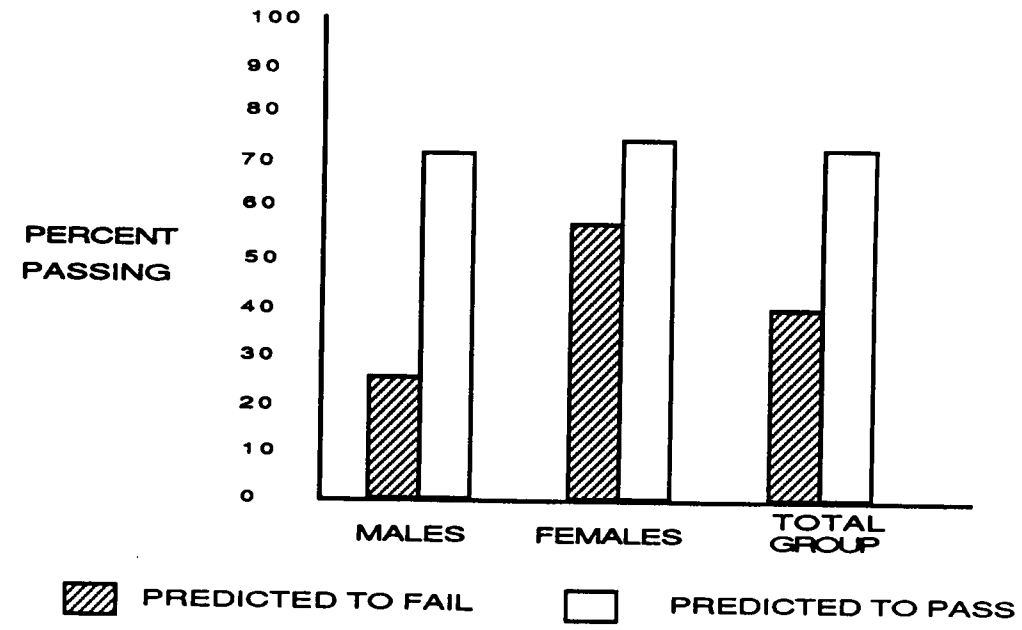


FIGURE 4: ANALYSIS OF MATHEMATICS COURSE PLACEMENT FOR TOTAL GROUP BY SEX WITH CALCULUS READINESS TEST: PERCENT PASSING

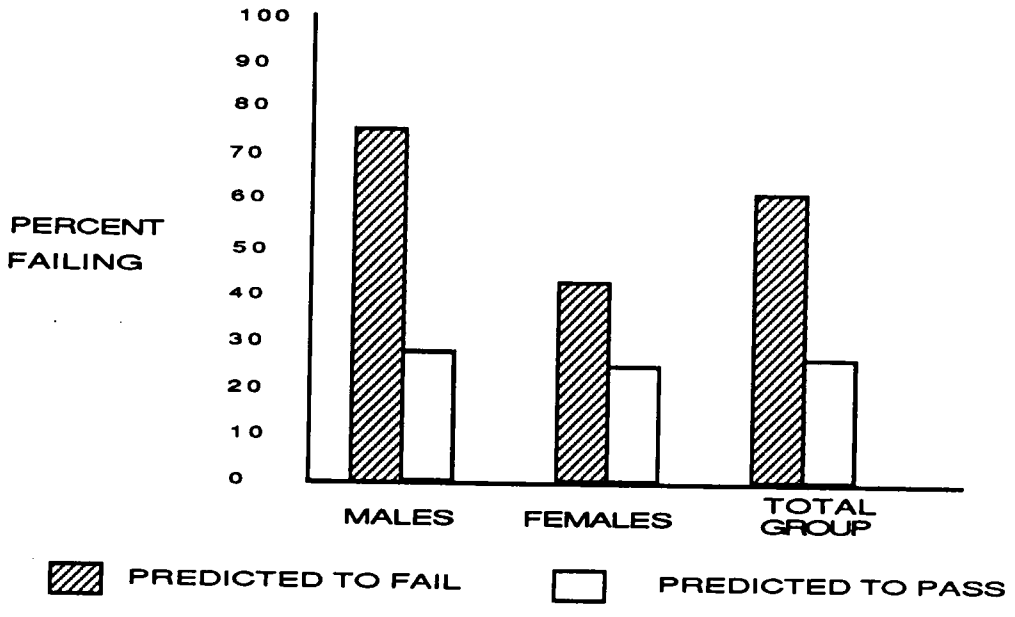


FIGURE 5: ANALYSIS OF MATHEMATICS COURSE PLACEMENT FOR TOTAL GROUP BY SEX WITH CALCULUS READINESS TEST: PERCENT FAILING

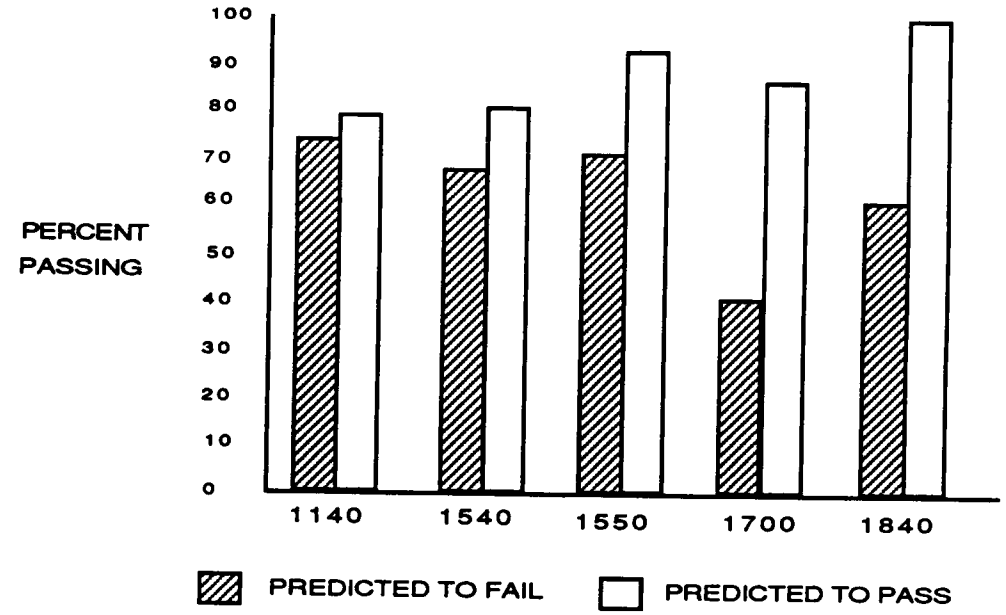


FIGURE 6: ANALYSIS OF MATHEMATICS COURSE PLACEMENT BY COURSES WITH ADVANCED ALGEBRA TEST: PERCENT PASSING

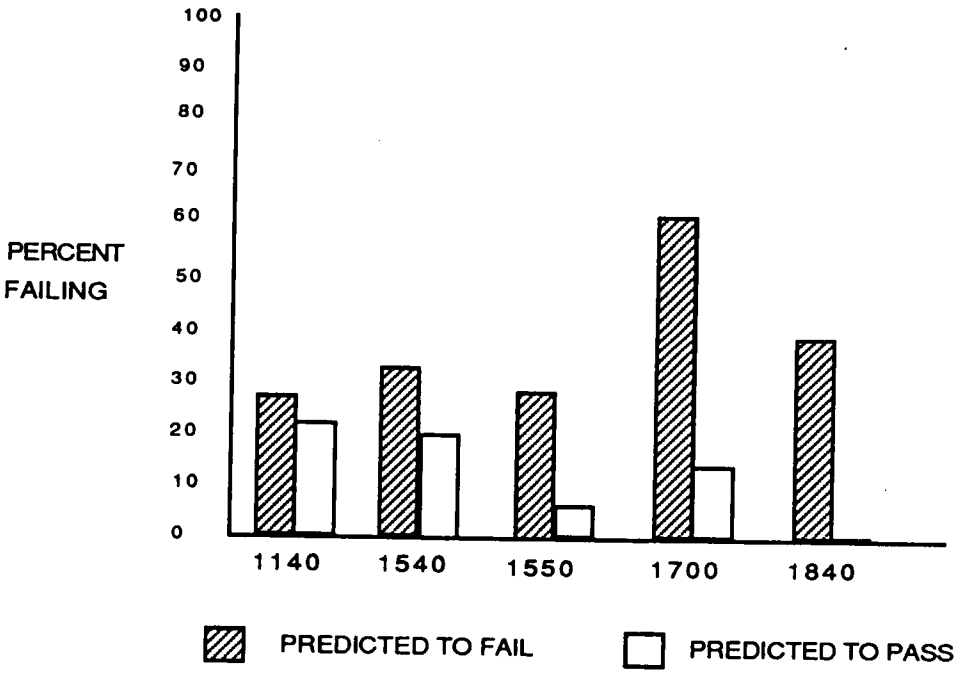


FIGURE 7: ANALYSIS OF MATHEMATICS COURSE PLACEMENT BY COURSES WITH ADVANCED ALGEBRA TEST: PERCENT FAILING

to fail actually passed. Figure 7 reveals a sharp difference among those failing who were predicted to pass (6%) and who were predicted to fail (28%). In the highest level mathematics courses, Mathematics 1700 and Mathematics 1840, the Advanced Algebra test did the best job of identifying potential passing and failing students. However, the fact that 49% of Mathematics 1700 students predicted to fail subsequently passed, and that 61% of Mathematics 1840 students predicted to fail also passed, indicates that this test tends to overpredict failure in general.

Figures 8 and 9 present the analysis of mathematics course placement by course using the Calculus Readiness test. No results are presented in these figures for Mathematics 1140 and 1540 since this test predicts all students in those courses to pass. An overwhelming 93% of the total group were predicted to pass Mathematics 1550 by this test. The percentage of correct pass predictions was thus quite high (83% predicted to pass actually passed). The students predicted to fail Mathematics 1550 actually passed at the rate of 57%. The test appears to overpredict passes, probably because the cut-off point in Mathematics 1550 was set too low. Forty-three percent of those predicted to fail Mathematics 1550 actually failed, while 17% predicted to pass subsequently failed (Figure 9). Among Mathematics 1700 students who were predicted to pass, 61% subsequently passed. No passing students were predicted to fail this course (Figure 8). All Mathematics 1700 students who were predicted to fail did fail, while 39% of those predicted to pass actually failed (Figure 9). In Mathematics 1840, among those predicted to pass, 70% did pass, while among those predicted to fail, 43% passed (Figure 8). Among those predicted to pass, 30% failed and among those predicted to fail, 57% passed (Figure 9).

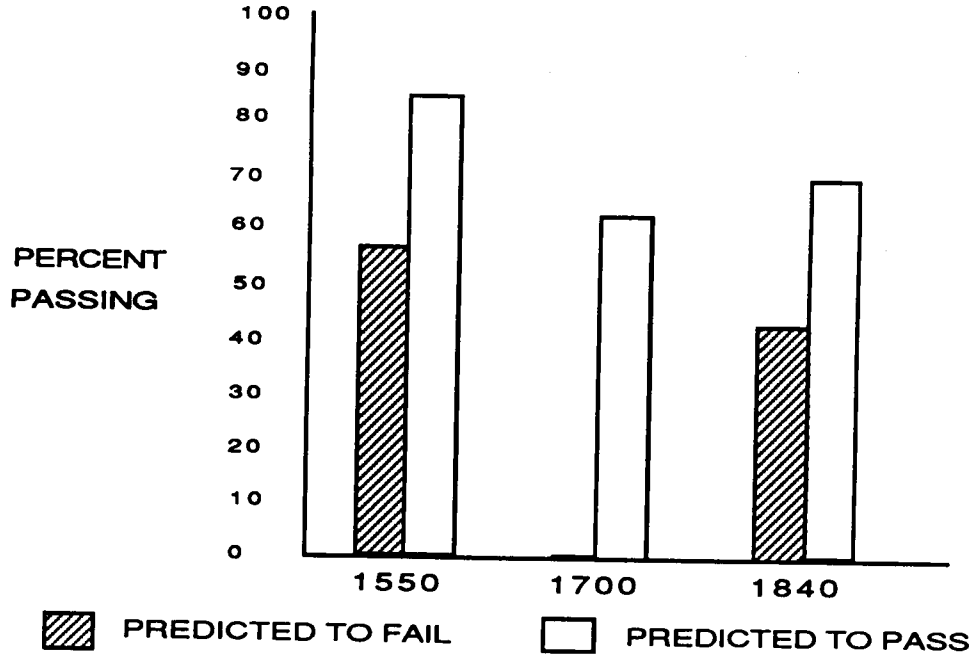


FIGURE 8: ANALYSIS OF MATHEMATICS COURSE PLACEMENT BY COURSES WITH CALCULUS READINESS TEST: PERCENT PASSING

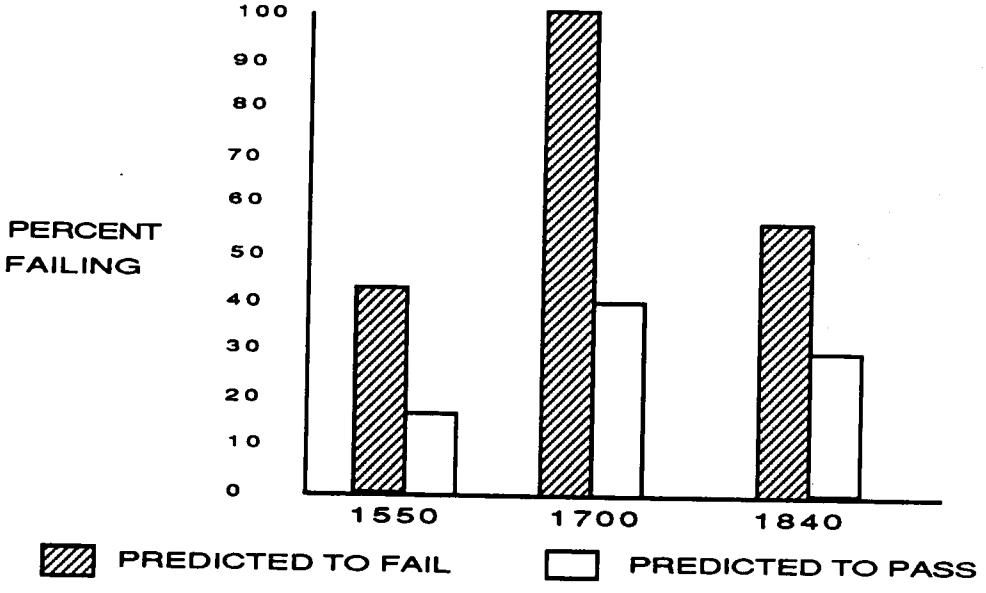


FIGURE 9: ANALYSIS OF MATHEMATICS COURSE PLACEMENT BY COURSES WITH CALCULUS READINESS TEST: PERCENT FAILING

Analysis for course placement based on high school type was also done. The four high school types studied were rural/big, rural/small, urban/big, and urban/small. However, due to the small sample sizes involved, tables are not presented. As before, it is apparent that in all cases the Advanced Algebra test tends to overpredict failure while the Calculus Readiness test tends to overpredict passing.

7. PAIRED COMPARISONS T-TEST

Table 35 presents the results of a paired comparisons T-test to determine whether the students who participated in the summer testing received significantly higher scores in the fall testing. While the scores on the Advanced Algebra test were not significantly different, it appears that the Calculus Readiness test scores were significantly higher in the fall than in the summer (alpha < 0.01), with a mean 1.39 points higher than the summer test mean.

The students who were tested twice by Calculus Readiness improved their scores. This might explain further why the Calculus Readiness test in general tended to overpredict passing. If the retested students had not received an advantage, the number of predicted passes may have been smaller.

TABLE 35

ADVANCED ALGEBRA AND
CALCULUS READINESS
PAIRED COMPARISONS T-TEST

VARIABLE	MEAN	STANDARD ERROR OF MEAN	T	PR > /T/
AADIFF	0.35	0.426	-0.82	0.4163
CRDIFF	-1.39	0.303	-4.59	0.0001

CHAPTER 5

FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

1. FINDINGS AND CONCLUSIONS

We began by defining a placement process in mathematics as a procedure which examines measures of student mathematical achievement and ability via high school records and test scores, and determines from these the entry level mathematics course which most closely matches the student's level of mathematical achievement. Through a placement process, one attempts to find the course which best matches a student's cognitive level in mathematics and optimizes the chance for success in that course. Valid placement schemes should thus be characterized by having a high proportion of students succeeding in courses in which they are predicted to succeed. An equally important measure of the validity of a placement procedure is the proportion of students who succeed in a course for which they are predicted to be unsuccessful. Valid placement schemes should be characterized by having a small proportion of students who succeed when they are predicted to fail a given course. Clearly, if students are "equally likely" to pass a course whether predicted to pass or fail by some placement scheme, then the placement scheme itself must be suspect. Thus, the validity of a placement scheme can be measured by comparing the proportions of correct pass predictions to incorrect fail predictions.

Regarding the research questions, we have the following findings:

1. Correlations between the predictors and criteria were, in general, significant. This implies that a great deal of latitude exists in the choice of predictors that can be used effectively.

2. Using the predictors selected for this study no prediction equations accounted for more than 55% of the variance in grades.

3. Placement seems to be affected by gender. Females appear to be able to pass higher level mathematics courses than their placement test score recommends that they take.

We defined a placement process to be effective if it correctly predicts success or failure for 75% to 85% of students. In addition, only about 15% to 25% of students who are predicted to fail should subsequently pass the course. The Advanced Algebra test administered in the fall of 1987 correctly predicted success for 85% of students while 61% of those predicted to fall managed to pass. This does not meet our criterion for an effective placement process. Students themselves might be willing to risk taking a higher level course than the placement test indicates if they feel that a 61% chance of passing is good enough. With 61% of the students who are predicted to fail actually passing, it seems that the Advanced Algebra placement test alone does not do a good job of differentiating between potentially successful and unsuccessful students.

Similar results are apparent for the Calculus Readiness. Seventy-three percent of those predicted to pass did pass and almost 40% of those predicted to fail also managed to pass. The Calculus Readiness test seems to be a little better, but it is still conceivable that some students would be willing to risk taking a higher level course with even a 40% chance of passing it.

These conclusions persist when sex differences are considered. The data regarding the Advanced Algebra test imply that, regardless of sex, a students' chances of succeeding in a mathematics course for which he/she is predicted to succeed is about 85% while his/her chance of succeeding when predicted to fail is close to 60%. Again, students who are eager to save time might consider a 60% chance of passing a course good enough when compared to an 85% chance and would possibly be willing to take the risk.

Females taking the Calculus Readiness test also have an almost even chance of passing whether predicted to pass or not, 75% compared to 57% . We have already commented on the fact that females tend to pass higher level courses for which placement indicates they will not succeed. The results for males taking the Calculus Readiness test, however, show that this test is effective for them. Seventy-one percent predicted to pass actually passed, while only 26% predicted to fail were able to pass.

When studied by course, these trends for the Advanced Algebra test persist. Mathematics 1140 students passed about equally often whether predicted to pass or not. For Mathematics 1540 students, those predicted to pass did pass at the rate of 80% while those predicted to fail passed at the rate of 67%. Similarly, for Mathematics 1550 students: 94% passed when predicted to pass and 72% passed when predicted to fail. The test is a little better for Mathematics 1700, where 40% of the students who were predicted to fail nevertheless passed. But in Mathematics 1840, 61% of those predicted to fail still passed. Based on these findings, we can say that the Advanced Algebra test fails to differentiate between those students who are able to pass and those who are not.

For the Calculus Readiness test when results are examined for Mathematics 1550 and 1840, the same conclusion can be reached. In Mathematics 1700, where no students who were predicted to fail managed to pass, almost the entire group, 93%, was predicted to pass.

Many students passed courses for which their placement test score indicated they were not ready. The results of the predicted vs. actual outcome analyses shows that the Advanced Algebra test overpredicted failure and the Calculus Readiness test overpredicted success in general. While better prediction can be made by simply adjusting the cut-off scores for placement as needed, it is rather more desirable to include other factors in the placement decision to improve the results. We feel that such factors should include students' own perceptions of their readiness, the task difficulty as they perceive it beforehand, how much time they normally spend studying mathematics, and the degree to which they attribute factors beyond their control to their performance in mathematics.

The prediction equations for the Advanced Algebra test accounted for 22% of the variance in grade for Mathematics 1140, 46% for Mathematics 1540, 31% for Mathematics 1550, 52% for Mathematics 1700, and 49% for Mathematics 1840. The prediction equations for the Calculus Readiness test accounted for 23% of the variance in grade for Mathematics 1140, 50% for Mathematics 1540, 28% for Mathematics 1550, 52% for Mathematics 1700, and 54% for Mathematics 1840. Both tests left a great deal unaccounted for in courses 1140 and 1550. For the other courses, the Calculus Readiness test accounted for more variance in grade than the Advanced Algebra test did. The results in Mathematics 1540 were surprising since this course is an algebra review course and one would not expect a test which determines

calculus readiness to be a better predictor of grade in this course than one which determines algebra readiness. One would expect that the Calculus Readiness test would be a better predictor of grades for students in Mathematics 1550 than for those in Mathematics 1540 because students in Mathematics 1550 should be ready for calculus.

Perhaps the clearest example of the danger of relying on one test score for placement came through the results of the predicted vs. actual performance analysis for females and males using the Calculus Readiness test. Females passed the course which the test considered above their ability at the rate of about 57%. This compares to 26% for males. The literature shows that females tend to obtain higher grades than males in mathematics courses in spite of the fact that they obtain lower scores on tests of ability in mathematics. Our data is consistent with the results found in the literature: females in our study tend to obtain higher mean course grades in upper level mathematics courses and higher mean HSGPAs than do males, even though males' mean ACTMATH test scores are higher than females'. There seems to be strong evidence here for the use of different cut-off scores for males and females since females tend to be misplaced into courses which are too easy for them when only a placement exam score is considered.

In the lowest level mathematics course, Mathematics 1140, neither the Advanced Algebra nor the Calculus Readiness test seemed appropriate as a predictor of either course grade or success. Neither test appeared as a significant contributor to prediction in the equations generated. The only significant correlate with course grade in Mathematics 1140 was the ACTMATH score. However, including high school mathematics credits in the prediction equation nearly doubles the variance in grade for which the equation accounts.

The Advanced Algebra test was a better correlate with grade than the Calculus Readiness test in Mathematics 1540. However, placement test scores did not account for enough variance in grades to be factors in the prediction equations for Mathematics 1540. Predicting grades for students in this course can be accomplished efficiently without using a placement test score but by relying on HSGPA, ACTMATH score, and high school mathematics credits instead.

As course level increases, the placement tests became better correlates with both grade and success, except that the correlation of Advanced Algebra with grade takes a slight dip from Mathematics 1540 to Mathematics 1550, as seen in Figure 10. The Calculus Readiness test accounts for more variance in grade than does the Advanced Algebra test only in the course Mathematics 1700.

Neither test contributed significantly to the amount of variance in grade for which the prediction equation accounted in Mathematics 1140 or Mathematics 1540. In Mathematics 1550, the Advanced Algebra score alone accounted for over 19% of the variance in grade. Including HSGPA, high school mathematics credits, and sex brought the total variance accounted for to 30%. Even though Mathematics 1550 is a calculus course, the Calculus Readiness test did not account for enough variance in grade to be a factor in the prediction equation. In Mathematics 1700, the Advanced Algebra test alone accounted for 34% of the variance in grade, compared to 29% accounted for by the Calculus Readiness test. Either test seems suited for prediction in Mathematics 1700. In Mathematics 1840, the Advanced Algebra test alone accounted for almost 37% of the variance in grade. The Calculus Readiness test accounted for about the same, 37%.

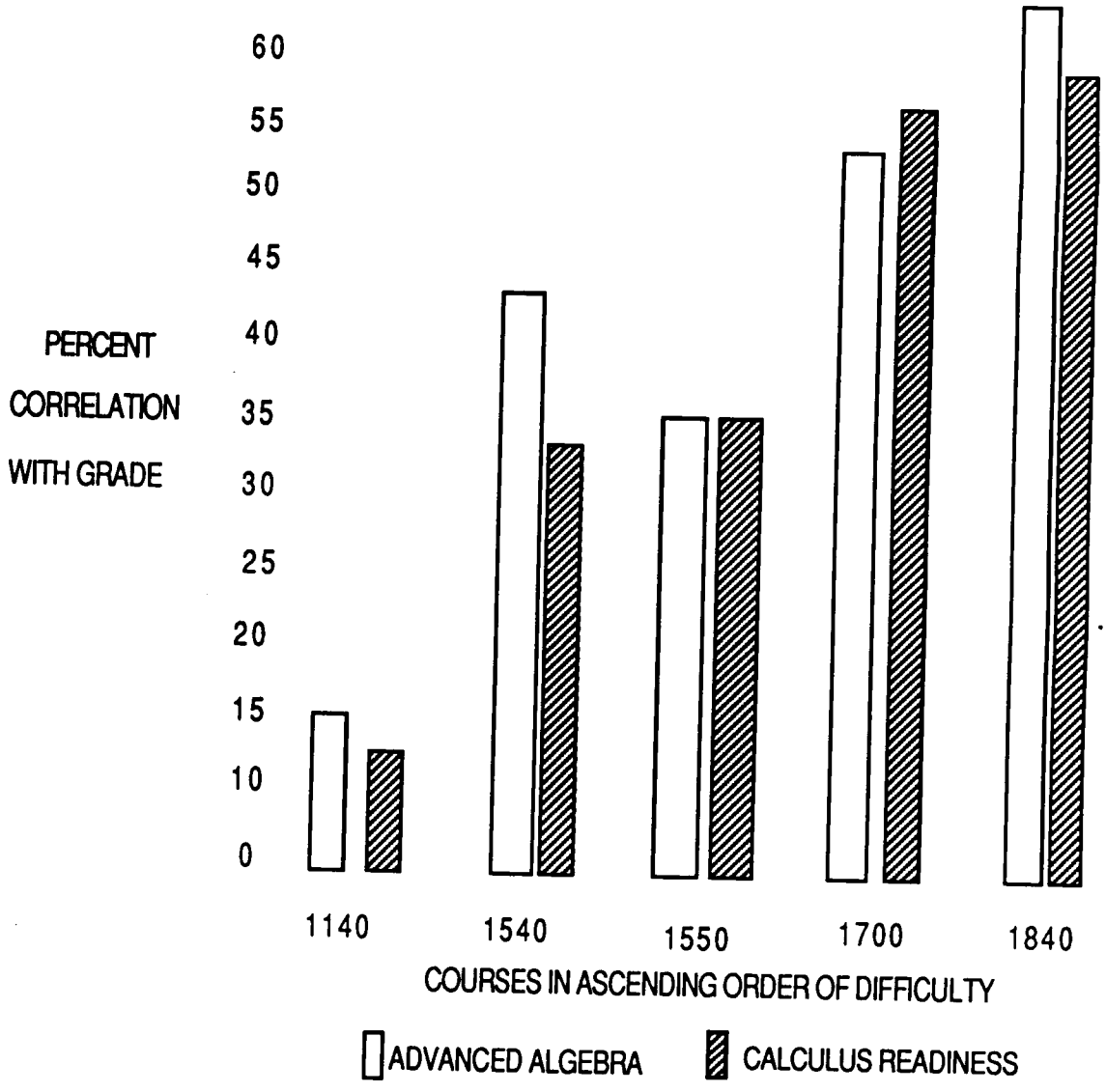


FIGURE 10. CORRELATIONS WITH GRADES FROM PREDICTION EQUATIONS

Because so much of the variance in grade was left unaccounted for by all the prediction equations (as much as 78% in lower level course and almost 50% in higher level courses), it is recommended that future research focus on noncognitive predictors.

2. RECOMMENDATIONS

The results of the present study indicate that differences on several variables existed between sections of each mathematics course. Differences existing between sections of mathematics courses need further study. This is especially true when the differences are in final course grade. Two possible explanations for such differences are a discrepancy in grading criteria or a preponderance of better students in one section. Future research should take such differences into account when prediction equations are generated which use variables that are affected by section differences.

Students' courses should be monitored to determine how placement affects retention and grade point average. A data base should be created which keeps placement test scores, HSGPA, ACT math score, high school mathematics credits, mathematics course grades, and mathematics course success measure, as well as other measures of mathematical ability and achievement. Such information can be used to refine the prediction procedure so that placement can be made more accurately for future students.

Rather than using the placement test exclusively, regression equations should be used which account for more variance. Such equations were found in this study. Each course has its own equation using its own set of best predictors. Of course, cut-off scores would have to be determined for such

equations to be useful. By including in the placement decision other variables besides a single placement test score, more accurate predictions of probable success in mathematics can be made, as evidenced by the amount of variance in grade for which our prediction equations accounted. Even keeping in mind that our results may have been confounded due to section differences and the effect of using volunteers, it still seems that a more satisfactory placement decision can be made for students when multiple factors are considered. Future study could determine the validity of this argument.

Experimentation with setting different cut-off scores on placement tests for males and females should be conducted if this test score alone is to be used for placement. Our results indicate that females have lower placement test scores but do better in higher level mathematics courses than males do. Future study could examine possible explanations for this phenomenon.

Samples of students in mathematics courses should be selected for follow-up study. Students themselves can provide valuable insight into the reasons they are successful or unsuccessful in mathematics courses. This insight can be used to sharpen the placement picture. Future study can focus on ways to incorporate such information into the placement process.

Finally, future research should experiment with constructing better placement tests than the ones used in this study. Such tests could be composed by studying the errors that students make in a mathematics course and which are judged to be caused by a lack of the prerequisite knowledge for the course. A list of questions could grow out of this list of errors.

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APPENDICES

APPENDIX A

Your section of Mathematics _____ has been selected for participation in a research project. The purpose of this study is to investigate the validity of a placement testing procedure in freshman mathematics at the University of Tennessee-Knoxville. The study will last from now until the end of Winter Quarter, 1988. You will be given two placement tests one day during the first week of classes. Part of your final exam will serve as a posttest. This part will be composed by your instructor, the investigator, and instructors teaching other sections of your mathematics class who are also participating in the study. Some of you will be contacted during Winter Quarter 1988 and invited to participate in an interview session where you will be asked to give your opinions regarding the reasons you feel that you received the grade you did. Finally, your high school grade point average and mathematics ACT score will be obtained for statistical analysis.

Your identity will be kept confidential. Only the investigator and the faculty advisor will have access to your pretest results, high school grade point average, and mathematics ACT score. The records used in this study will be stored in a locked file cabinet in Room 214, Ayres Hall.

Your participation in this study will be of great benefit to the Mathematics Department and future UTK students in implementing a reliable placement program. You will be free to refuse or end participation at any time without penalty.

If you have any questions about the study either now or later, please feel free to contact Mary R. Daunis, 403A Ayres Hall, UTK, 974-2461.

I have read and understood the explanation of this study and agree to participate. I certify that today I am eighteen years of age or older.

_____ _____

NAME DATE

_____

SIGNATURE

To:
From: Mary R. Daunis

Your section of Mathematics _____ has been selected for participation in a research project which will serve as my dissertation study for the Ph.D in Education degree. The purpose of this study is to investigate the validity of a placement testing procedure in freshman mathematics at the University of Tennessee-Knoxville. The study will extend from now until the end of Winter Quarter, 1988. Your students will be given two placement tests during the first week of classes. These will take a total of fifty minutes to complete. Part of your final exam will serve as a posttest. This part, approximately ten questions, will be composed jointly by all participating instructors of your course and myself.

Your participation in this study will greatly benefit the Mathematics Department and future UTK students in implementing a reliable placement program. Thus your cooperation will be greatly appreciated.

In the event that any of your students decline to participate in the study, it will be necessary that you give them some other work to do or that you simply dismiss them during the administering of the placement tests. In addition, you may give such students a different final exam.

If you have any questions about this research either now or later, please contact me at 403A, Ayres Hall, 974-4339 or at 584-7051. Please return this form to my mailbox today.

I have read and understood the explanation of this study and agree to participate.

_____ _____
NAME DATE

_____
SIGNATURE

I decline to participate in this study.

_____
NAME

APPENDIX B

MATHEMATICS TEST AA/2A

Each question is followed by five suggested answers, labeled a) through e). Select the one best answer to each question. Do not spend too much time on any one question. Indicate your answers as directed by the test administrator.

Suggested time: 30 minutes

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1. If $x = \frac{1}{2}$, then $x + \frac{1}{x} - 1 =$

a) $-\frac{1}{2}$ b) 0 c) $\frac{1}{2}$ d) $\frac{3}{2}$ e) $\frac{5}{2}$

---

2. If $\frac{x}{4} + 1 = \frac{5}{3}$, then $x =$

a) $\frac{8}{9}$ b) $\frac{8}{3}$ c) $\frac{19}{3}$ d) $\frac{20}{3}$ e) $\frac{32}{3}$

---

3. $\frac{u}{2v} + \frac{u}{5v} =$

a) $10uv$ b) $\frac{7u}{10v}$ c) $\frac{2u}{7v}$ d) $7uv$ e) $\frac{7u}{10v^2}$

---

4. If $x > 0$, then $\sqrt{9x^2 + 16x^2} =$

a) x b) $3x$ c) $5x$ d) $7x$ e) $25x$

---

5. If $\log_{10} x = 3$, then $x =$

a) $\frac{1}{1000}$ b) $\frac{3}{10}$ c) 10 d) 100 e) 1000

---

6. $\frac{x + 1}{x^2 - 4} \cdot \frac{4x + 8}{2x + 2} =$

a) $\frac{-3}{2x + 2}$ b) $\frac{2}{x - 2}$ c) $x + 4$ d) $\frac{2}{x}$ e) $\frac{6}{x - 4}$

---

7. $(27)^{2/3}(81)^{1/4} =$

a) 3 b) 9 c) 27 d) 81 e) 243

---

8. Let $f(x) = x^2 - kx + 2$. If $f(2) = 4$, then $k =$

a) -5 b) -1 c) 1 d) 2 e) 4

---

9. $\frac{1}{1 + \sqrt{3}} =$

a) $\frac{1 - \sqrt{3}}{2}$ b) $\frac{\sqrt{3} - 1}{2}$ c) $\frac{\sqrt{3} - 1}{8}$ d) $\frac{1 + \sqrt{3}}{-8}$ e) $\frac{1 + \sqrt{3}}{2}$

---

10. If $x > 1$, then $|1 - x| =$

a) 0 b) $1 - x$ c) $1 + x$ d) $-1 - x$ e) $-1 + x$

---

11. If $ax - b = c(x + a)$, then $x =$

a) $\frac{b + ac}{a - c}$ b) $\frac{b + ac}{a + c}$ c) $\frac{a + b}{a - c}$ d) $\frac{a - b}{a - c}$ e) $\frac{a + b}{a + c}$

---

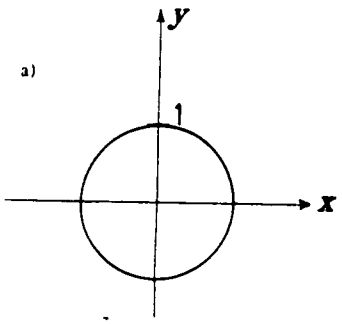
12. $\log_4(64) =$

a) $\frac{1}{4}$ b) $\frac{1}{3}$ c) 3 d) 8 e) 16

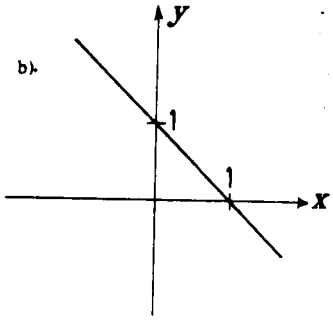
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13. The graph of $x^2 + y = 1$ is

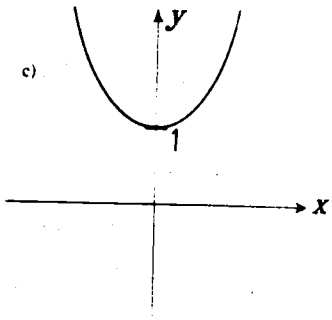
a)



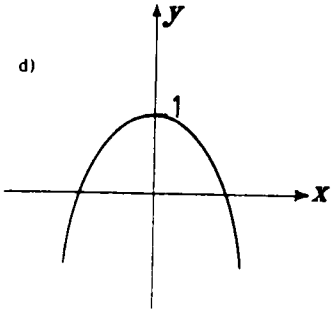
b)



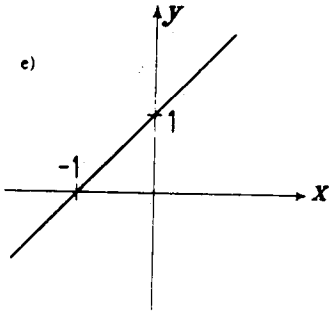
c)



d)



e)



---

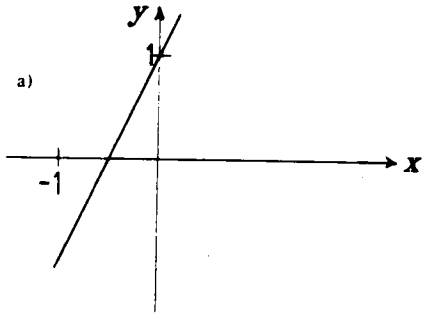
14. A solution of $x^2 + 2x = -5$ is

a) -7 b) -5 c) $-1 + 2i$ d) 1 e) i

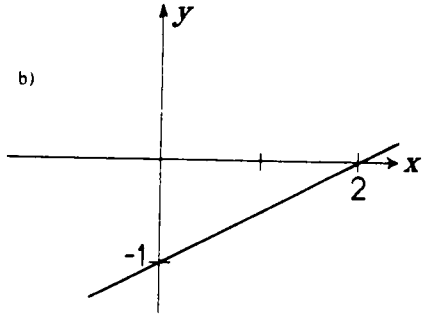
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15. The graph of $y = 1 + 2x$ is

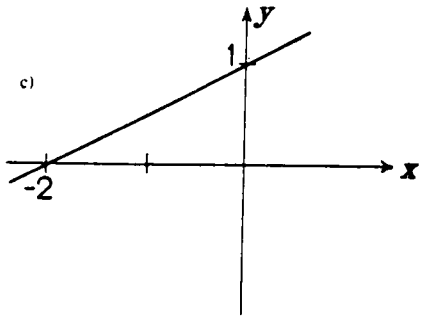
a)



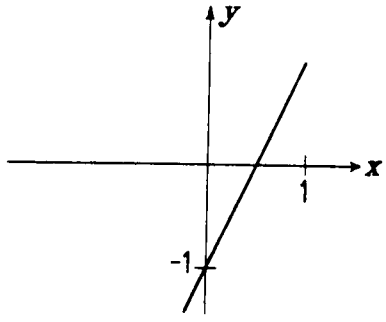
b)



c)



d)



e) none of these

---

16. $\frac{x^3 + 8}{x + 2} =$

a) $x^2 + 2x + 4$ b) $x^2 + 4$ c) $x^2 + 6$ d) $x^2 + 4x + 4$ e) $x^2 - 2x + 4$

---

17. If $x > 0$ and $y > 0$, then $\sqrt{8\sqrt{4x^6y^4}} =$

a) $8xy\sqrt{x}$ b) $4xy\sqrt{2x}$ c) $4xy\sqrt{x}$ d) $4x^2y$ e) $4x^3y^2\sqrt{2}$

---

18. If $5^x = 2$, then $x =$

a) $\frac{2}{5}$ b) $\frac{5}{2}$ c) $\log_2(5)$ d) $\log_5(2)$ e) $\log_{10}\left(\frac{2}{5}\right)$

---

19. Which of the following are factors of $x^4 - 16$?

I. $x - 2$ II. $x + 2$ III. $x^2 + 4$

a) I only b) II only c) III only d) I and II only e) I, II and III

---

20. $x^2 - 11x < 12$ is equivalent to

a) $2 < x < 6$ b) $3 < x < 4$ c) $x < 3$ or $x > 4$ d) $-1 < x < 12$ e) $x < -1$ or $x > 12$

---

21. The graphs of the equations $\begin{cases} x - 3y = 1 \\ 2x + 6y = 2 \end{cases}$ consist of

a) two distinct parallel lines
b) one line
c) two lines intersecting where $y = 4$
d) two lines intersecting where $x = 1$
e) two lines intersecting where $x = 2$

---

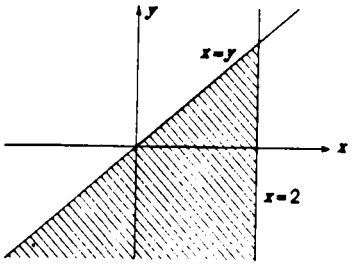
22. If $(x - k)^2 = k^2 + 2x + x^2$, then $k =$

a) -2 b) -1 c) 0 d) 1 e) 2

---

23. The shaded region is described by the inequalities

a) $x \geq y$ and $x \leq 2$
b) $x \leq y$ and $x \leq 2$
c) $x \geq y$ and $x \geq 2$
d) $x \leq y$ and $x \geq 2$
e) $x \geq y$ and $y \leq 2$



24. If $f(x) = x^2 - 3$ and $g(x) = 2x + 4$, then $f(g(2)) =$

a) 1 b) 5 c) 6 d) 8 e) 61

25. The solution set for $x - 4 - \sqrt{9x} = 0$ consists of

a) exactly one positive number
b) exactly one negative number
c) exactly one positive number and one negative number
d) exactly two positive numbers
e) exactly two negative numbers

MATHEMATICS TEST CR/1B

Each question is followed by five suggested answers, labeled (a) through (e). Select the one best answer to each question. Do not spend too much time on any one question. Indicate your answers as directed by the test administrator.

Suggested time: Entire Test, 30 minutes
Part 1, 25 minutes

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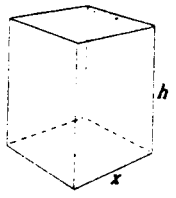
PART I

(In all graphing problems, assume the usual coordinate system.)

1. The box pictured on the right has a square base and a closed top.

   Express its surface area in terms of x and h.

   (a) $x^2 + 4xh$ (b) $8x + 4h$ (c) $4x + h$ (d) hx^2 (e) $2x^2 + 4xh$



2. If f(x) is a function whose graph is the parabola sketched to the right, then $f(x) < 0$ whenever

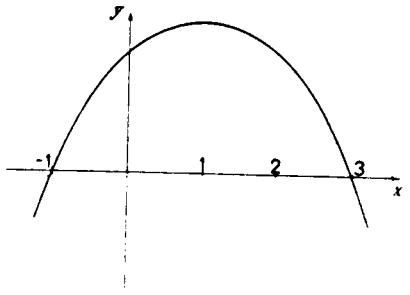
   (a) $x < 0$

   (b) $x < 3$

   (c) $x > -1$

   (d) $x < -1$ or $x > 3$

   (e) $-1 < x < 3$



3. If money in a bank doubles every 5 years, then by what factor does it increase over a 20 year period?

   (a) 4 (b) 8 (c) 12 (d) 16 (e) 20

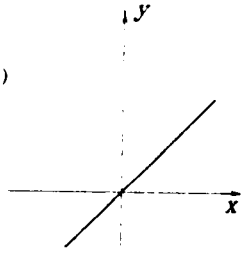
4. The y-coordinate of the intersection of the graphs of $x - 2y = 6$ and $x + y = -3$ is

   (a) -3 (b) -2 (c) -1 (d) 1 (e) 3

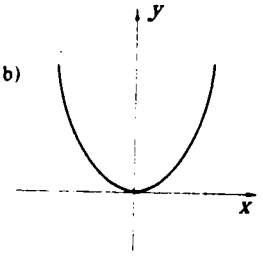
5. Definition: A function is *even* if $f(-x) = f(x)$ for each x in the domain of f.

   Which of the functions whose graphs are shown is even?

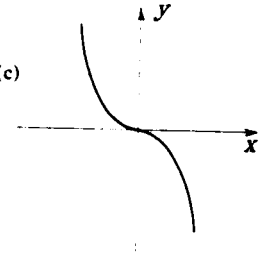
(a)



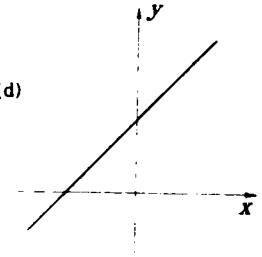
(b)



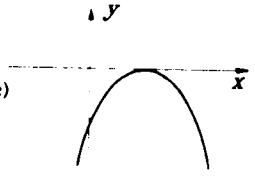
(c)



(d)



(e)

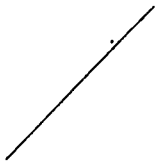
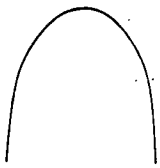
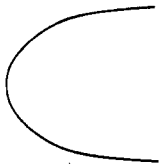
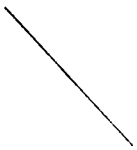


6. $8^{-1/3}9^{1/2} =$

(a) 6 (b) -6 (c) $(72)^{-1/6}$ (d) $\frac{2}{3}$ (e) $\frac{3}{2}$

---

7. Which of the following best resembles the graph of $y = \frac{1}{2}x^2 - 3x + 1$?

(a)  (b)  (c)  (d)  (e) 

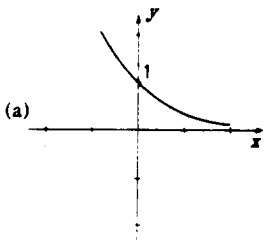
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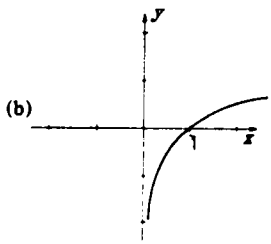
8. If $\log_3(x + 1) = 2$, then $x =$

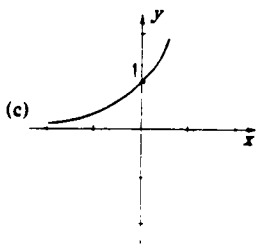
(a) 5 (b) 6 (c) 7 (d) 8 (e) $\frac{2}{\log_3} - 1$

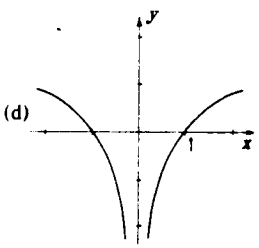
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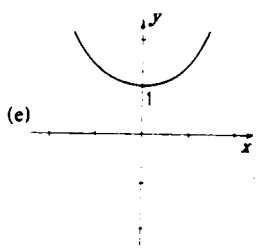
9. Which of the following curves best resembles the graph of $f(x) = 3^x$?

(a) 

(b) 

(c) 

(d) 

(e) 

---

10. If $\frac{(2x + 1)(x - 1)}{(x + 1)} = 0$, then $x =$

(a) -1 or 1 (b) $-\frac{1}{2}$ or 1 (c) $-\frac{1}{2}$, 1 or -1 (d) $\frac{1}{2}$ or -1 (e) $\frac{1}{2}$, 1 or -1

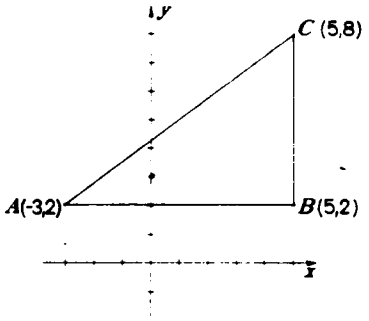
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11. The symbol "$\approx$" means "is approximately equal to." Given that $3^7 \approx 2000$, then $3^{14} \approx$

(a) 4,000 (b) 40,000 (c) 400,000 (d) 4,000,000 (e) $2{,}000^8$

12. In the given figure, the distance between points A and C is

(a) 8 (b) 10 (c) 12 (d) 14 (e) 16



---

13. If $f(x) = \frac{2x + 6}{x + 2}$, then $f(a + 2) =$

(a) $\frac{5}{2}$ (b) $\frac{2a + 8}{a + 4}$ (c) $\frac{2a + 10}{a + 4}$ (d) $\frac{2a + 6}{a + 2}$ (e) $\frac{2a + 6}{a + 4}$

---

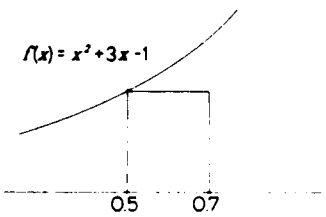
14. The graph of the equation $y = -5x + 3$ is

(a) a horizontal line (b) a line rising to the right
(c) a vertical line (d) a line falling to the right
(e) not a line

---

15. The area of the rectangle pictured on the right is

(a) 0.015 (b) 0.15 (c) 0.2 (d) 0.35 (e) 0.75



---

16. The quantity $a + b$ is a factor of how many of the following:

$a^2 - b^2$ $a^2 + b^2$ $a^3 - b^3$ $a^3 + b^3$

(a) 0 (b) 1 (c) 2 (d) 3 (e) 4

---

17. Suppose the sides of a rectangle with length x and width y are each doubled.

The increase in the area of the rectangle is

(a) xy (b) 2xy (c) 3xy (d) 4xy (e) x^2y^2

---

18. $|x - 2| \leq 1$ is equivalent to

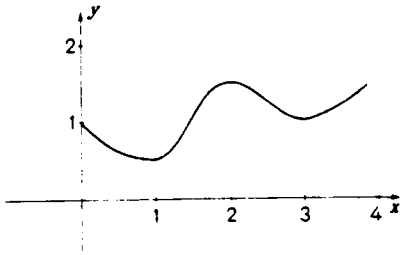
(a) $x \geq 3$ (b) $x \leq 1$ (c) $-3 \leq x \leq -1$ (d) $1 \leq x \leq 3$ (e) $-3 \leq x \leq 3$

---

19. The length of a certain rectangle is 3 meters more than twice its width. If the perimeter of the rectangle is 90 meters, then the width of the rectangle is

(a) 6 m (b) 12 m (c) 14 m (d) 16 m (e) 29 m

20. Definition: A function f(x) has a *minimum value at the number c* if $f(c) \leq f(x)$ for every x in the domain of f(x). If the domain of the function whose graph appears on the right is [0, 4], at which number does the function have a minimum value?



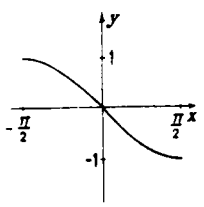
(a) 0 (b) 1 (c) 2 (d) 3 (e) 4

PART II

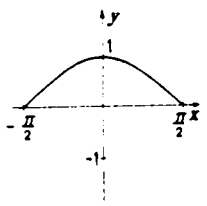
(Assume radian measure in all trigonometric expressions.)

21. Which of the following best represents the graph of $y = \sin x$ for x between $-\frac{\pi}{2}$ and $\frac{\pi}{2}$?

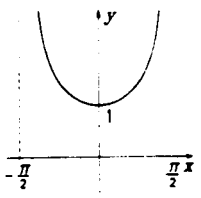
(a)



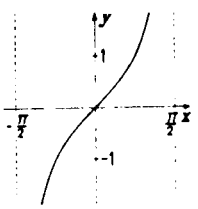
(b)



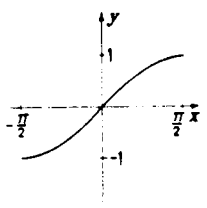
(c)



(d)



(e)



22. $1 - \sin^2\theta =$

(a) $-\cos^2\theta$ (b) $\cos^2\theta$ (c) $\cos\theta$ (d) $\csc^2\theta$ (e) $\cos 2\theta$

23. If $f(x) = \cos 3x$, then $f(\pi/6) =$

(a) 0 (b) $\frac{1}{\sqrt{2}}$ (c) $\frac{1}{2}$ (d) $\frac{\sqrt{3}}{2}$ (e) 1

24. For which value of x is tan x *not* defined?

(a) $-\pi$ (b) $-\frac{\pi}{2}$ (c) 0 (d) $\frac{\pi}{4}$ (e) $\frac{\pi}{3}$

25. $\sin\theta \tan\theta \csc^2\theta =$

(a) $\tan\theta \sin^2\theta$ (b) $\cos\theta$ (c) $\sin\theta$ (d) $\tan\theta$ (e) $\sec\theta$

APPENDIX C

1140

_____ 1. Suppose you flip a coin and then roll a die. The probability P(heads or a five) is

a) 2/3 b) 7/12 c) 1/4 d) 1/2 e) 3/4

_____ 2. Suppose you draw a card from a deck of playing cards. Find the probability P(even number| not a face card). (An ace is not a face card.)

a) 5/13 b) 1/3 c) 1/2 d) 2/13 e) 2/3

_____ 3. How many different arrangements are there of the letters in the word *mississippi* ?

a) 11! b) 207900 c) 21! d) 3850 e) 34650

_____ 4. In scientific notation 0.000456 is

a) 4.56×10^4 b) 4.56×10^{-4} c) 4.56×10^{-5}
d) 4.56×10^5 e) 0.456×10^{-3}

_____ 5. Solve for x: $6(x - 2) = 4 + 5(x - 4)$

a) x=4 b) x=2 c) x=-4 d) x=-2 e) x=8

_____ 6. If Jello is on sale for 5 boxes for \$1.09, and if a single box costs \$0.22, how much would 13 boxes cost?

a) \$2.83 b) \$2.74 c) \$2.84 d) \$2.73 e) \$2.85

_____ 7. Write as a fraction: $3.\overline{91}$

a) 391/100 b) 391/1000 c) 388/99
d) 3888/999 e) 399/100

_____ 8. If the universe is U = {1,2,3,4,5,6,7,8,9,10}, A = {1,2,3,4,9}, and B = {2,6,7,8,9}, then $A \cup \bar{B}$ is

a) {1,2,3,4,5,9,10} b) {1,2,3,4,6,7,8,9}
c) {1,2,3,4,9} d) {1,3,4}
e) {2,9}

1540

_____ 1. $\frac{x^3 + 8}{x + 2}$ =

a) $x^2 + 2x + 4$ b) $x^2 + 4$ c) $x^2 + 6$
d) $x^2 + 4x + 4$ e) $x^2 - 2x + 4$

_____ 2. The solution set for $x - 4 - \sqrt{9x} = 0$ consists of

a) exactly one positive number
b) exactly one negative number
c) exactly one positive and one negative number
d) exactly two negative numbers
e) exactly one negative number

_____ 3. Let $f(x) = \sqrt{3x+9}$. The largest possible domain of f is

a) $\{x: x \geq 0\}$ b) $\{x: x \geq -3\}$ c) $\{x: x \leq -3\}$
d) $\{x: x \geq 3\}$ e) $\{x: x \geq -9\}$

_____ 4. The solution set for $x + 1 \leq 3x + 2$ is

a) $\{x: x \leq -1/2\}$ b) $\{x: x \geq -1/2\}$ c) $\{x: x \leq 1/2\}$
d) $\{x: x \geq 1/2\}$ e) $\{x: x \leq 1\}$

_____ 5. If $g(x) = 2x - 3$ then $g(x + h)$ =

a) $2x - 3 + h$ b) $2x + 3 - h$ c) $2x + 2h - 3$
d) $2x - 3 - h$ e) $2x - 2h + 3$

_____ 6. $(2x^2y^{1/2})^6$ =

a) $64x^{12}y^3$ b) $2x^8y^{13/2}$ c) $12x^{12}y^3$
d) $12x^8y^{13/2}$ e) $12x^8y^{13/2}$

_____ 7. If $\sqrt{x} - 1 = 1$ then x =

a) 4 b) -4 c) 4 or -4 d) $\sqrt{2}$ e) $\pm\sqrt{2}$

_____ 8. How many positive real roots does $3x^3 - 7x^2 - 7x - 3 = 0$ have?

a) 1 b) 0 c) 2 or 0 d) 2 e) 3 or 1

_____ 1. $\frac{x^3+8}{x+2}$ =

a) x^2+2x+4 b) x^2+4 c) x^2+6
d) x^2+4x+4 e) x^2-2x+4

_____ 2. If $f(x) = x^5 - x^{2/3} + 6x$ then $f'''(x)$ =

a) $60x^2+(8/27)x^{7/3}$

b) $60x^2+(8/27)x^{-1/3}$

c) $60x^2-(8/27)x^{-1/3}$

d) $60x^2+(8/27)x^{1/3}$

e) $60x^2-(8/27)x^{-7/3}$

_____ 3. $\int (x^5 + 2x^3)\,dx$ =

a) $5x^5 + 6x^2 + C$

b) $(1/6)x^6 + (1/2)x^4 + C$

c) $6x^6 + 8x^4 + C$

d) $6x^6 + (2/3)x^4 + C$

e) $5x^4 + 6x + C$

_____ 4. If $f'(x) < 0$ for $x < -1$ and $f'(x) > 0$ for $x > -1$ and if $f'(x) = 0$ only for $x = -1$, then $f(x)$ has a(n) _____ at $x = -1$.

a) zero
b) y-intercept
c) point of inflection
d) absolute maximum
e) absolute minimum

_____ 5. Suppose $f(x)$ is defined for all real numbers. If $f'(x) = 4-x^2$, then the critical values are

a) 2 and -2 only b) 2 only c) -2 only
d) 2, -2, and 0 only e) 0 only

_____ 6. If $f(x) = x^3 - 3x + 2$, then the graph of f _____ at $x = -2$.

a) is concave up and decreasing

b) is concave up and increasing

c) is concave down and increasing

d) is concave down and decreasing

e) cannot be continuous

_____ 7. $\lim_{h \to 0} \frac{h^2 - 6h}{h} =$

a) undefined b) 1 c) -6 d) 6 e) 0

_____ 8. The height f(t) from ground level of a falling rock is given by $f(t) = 200 - 16t^2$, $t \geq 0$, f in feet, t in seconds. The velocity at time $t = 3$ is

a) -56 ft/sec b) -96 ft/sec c) 56 ft/sec
d) 96 ft/sec e) -32 ft/sec

1700

_____ 1. Suppose the sides of a rectangle with length x and width y are each doubled. The increase in area of the rectangle is

a) xy b) 2xy c) 3xy d) 4xy e) x™y™

_____ 2. $(\sin\theta)(\tan\theta)(\csc^2\theta) =$

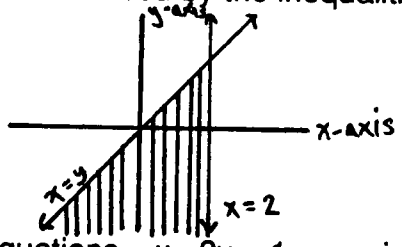
a) $(\tan\theta)(\sin^2\theta)$ b) $\cos\theta$ c) $\sin\theta$
d) $\tan\theta$ e) $\sec\theta$

_____ 3. The solution set for $x - 4 - \sqrt{9x} = 0$ consists of

a) exactly one positive number
b) exactly one negative number
c) exactly one positive and one negative number
d) exactly two negative numbers
e) exactly one negative number

_____ 4. The shaded region is described by the inequalities

a) $x \geq y$ and $x \leq 2$
b) $x \leq y$ and $x \leq 2$
c) $x \geq y$ and $x \geq 2$
d) $x \leq y$ and $x \geq 2$
e) $x \geq y$ and $y \leq 2$



_____ 5. The graphs of the equations $x - 3y = 1$ consist of
$2x + 6y = 2$

a) two distinct parallel lines
b) one line
c) two lines intersecting where y = 4
d) two lines intersecting where x = 1
e) two lines intersecting where x = 2

_____ 6. The equation $2^5 = 32$ is equivalent to

a) $\log_2 5 = 32$ b) $\log_5 2 = 32$ c) $\log_2 32 = 5$
d) $\log_{32} 5 = 2$ e) $\log_{32} 2 = 5$

_____ 7. If $f(x) = x^2+1$, then $f(1+h) =$

a) $3 + h^2$ b) $1 + 2h + h^2$ c) $2 + 2h + h^2$
d) $2 + h^2$ e) $1 + h^2$

_____ 8. $(-27)^{2/3}(4)^{-5/2} =$

a) 9/32 b) 2592 c) -9/32
d) 288 e) none of these

_____ 1. GIVEN A LINE WITH EQUATION AX + BY + C = 0, WHERE A AND B ARE NOT ZERO, THE SLOPE OF A LINE PERPENDICULAR TO THIS LINE IS

A) -A/B B) A/B C) -B/A D) B/A E) -C/B

_____ 2. GIVEN A FUNCTION f(x) SUCH THAT

$$\lim_{x \to 2} \frac{f(x) - f(2)}{x - 2}$$

EXISTS, THIS LIMIT IS

A) f'(2) B) IMPOSSIBLE TO DETERMINE C) f(2)
D) ZERO E) UNDEFINED

_____ 3. IF f(2) = 1, f'(2) = -1, g(2) = 2, g'(2) = -2, THEN THE VALUE OF $D_x[f(x)g(x)]$ FOR X = 2 IS

A) -7 B) 0 C) -4
D) IMPOSSIBLE TO DETERMINE E) 1

_____ 4. AN EQUATION FOR THE LINE TANGENT TO THE GRAPH OF f(x) = 1/x AT THE POINT P(2, 1/2) IS

A) y - 1/2 = -4(x - 2) B) y - 2 = 4(x - 1/2)
C) y - 1/2 = -1/4(x - 2) D) y - 2 = 1/4(x - 1/2)
E) y - 2 = -1/4(x - 1/2)

_____ 5. IF f''(3) = -1 THEN

A) f IS INCREASING AT X = 3
B) f IS DECREASING AT X = 3
C) f IS CONCAVE UP AT X = 3
D) f IS CONCAVE DOWN AT X = 3
E) THE POINT (3,-1) IS A POINT OF INFLECTION

_____ 6. $(\sin\theta)(\tan\theta)(\csc^2\theta) =$

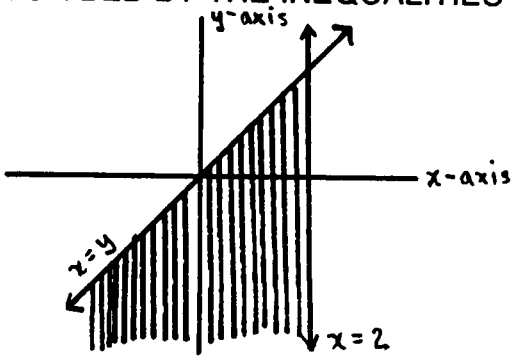
A) $(\tan\theta)(\sin^2\theta)$
B) $\cos\theta$
C) $\sin\theta$
D) $\tan\theta$
E) $\sec\theta$

_____ 7. THE GRAPHS OF THE EQUATIONS $\begin{matrix} x - 3y = 1 \\ 2x + 6y = 2 \end{matrix}$ CONSIST OF

A) TWO DISTINCT PARALLEL LINES
B) ONE LINE
C) TWO LINES INTERSECTING WHERE Y = 4
D) TWO LINES INTERSECTING WHERE X = 1
E) TWO LINES INTERSECTING WHERE X = 2

_____ 8. THE SHADED REGION IS DESCRIBED BY THE INEQUALITIES

A) $x \geq y$ and $x \leq 2$
B) $x \leq y$ and $x \leq 2$
C) $x \geq y$ and $x \geq 2$
D) $x \leq y$ and $x \geq 2$
E) $x \geq y$ and $y \leq 2$



VITA

Mary R. Daunis was born in Vacherie, Louisiana, on February 14, 1953. She attended elementary and high school in Thibodaux, Louisiana, graduating from Edward Douglas White Catholic High School in May, 1971. The following September, she entered the University of New Orleans (UNO), and received the Bachelor of Education degree in December, 1974. In the fall of 1980, she accepted a graduate teaching assistantship at UNO, and began study toward a Master of Science in Mathematics degree. This degree was awarded in May, 1982.

Ms. Daunis began graduate studies at the University of Tennessee, Knoxville, in September, 1982. She received the Doctor of Philosophy degree in December, 1988.

The author is a member of the Mathematical Association of America and the National Council of Teachers of Mathematics. She has accepted a mathematics teaching position at St. Cloud State University, St. Cloud, Minnesota.