PREDICTING UNDERGRADUATE MATHEMATICS SUCCESS: AN ANALYSIS OF UCDHSC PLACEMENT METHODS AND THE ACCUPLACER EXAM

by

Gary A. Olson

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This thesis for the Master of Science

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Gary A. Olson

has been approved

by

Michael Jacobson

William Briggs

Midge Cozzens

Date

Olson, Gary A. (M.S., Applied Mathematics)

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Thesis directed by Professor Michael Jacobson

ABSTRACT

Predicting student success has long been a question of interest for admission counselors throughout the United States. With the changing face of the nation's post-secondary population, a need has also developed for mathematics departments to address this question.

Existing research examines the validity of several methods designed for predicting undergraduate success. High school record, standardized test scores, extra-curricular activities and combinations of all three have historically been successful predictors. However, limited research has been conducted on predicting success in lower-level mathematics courses.

In recent years standardized test scores have become less valuable for placing students in lower level mathematics courses; placement exams such as ACCUPLACER have taken their place. Validity studies for these exams are crucial for institutions to analyze cut-off scores and ensure students are appropriately placed in courses that match their skill-level.

In June 2003, the Colorado Commission of Higher Education (CCHE) approved three tests for the purpose of entry and secondary-level assessment: the

ACT Assessment Test, the College Board Scholastic Aptitude Test, and the College Board ACCUPLACER. In Spring 2004, the University of Colorado at Denver and Health Sciences Center (UCDHSC) began using ACCUPLACER scores as mandatory placement criteria for all mathematics students enrolling in three courses, Analytical Geometry & Calculus I, College Algebra, and Algebra for Social Sciences and Business. Two of the initial goals of the placement procedure were to lower withdrawal rates and increase passing (A/B/C) rates for the three courses.

This thesis begins with a literature search and analysis of past research devoted to predicting college success. Major studies from 1980 to 2004 are presented and compared. Research on the prediction of lower-level undergraduate mathematics success is also discussed as well as two current studies of mathematics placement validity.

The ACCUPLACER Exam is then analyzed along with a comparison of placement techniques for different post-secondary institutions throughout Colorado. UCDHSC course data are then analyzed and predictors of mathematics success are discussed. Finally, statistical analysis is performed for all three classes and conclusions are drawn about the impact of ACCUPLACER on both withdrawal and passing rates.

This abstract accurately represents the content of the candidate's thesis. I recommend its publication.

Signed ________________________________
Michael Jacobson

DEDICATION

This thesis is dedicated to my parents and three sisters for all of their love and support during my academic pursuits.

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1. Introduction

Post-secondary mathematics departments currently use a variety of methods to place mathematics students in courses commensurate with their abilities. Each institution develops placement techniques based upon curriculum, student population, methodology, and placement test accessibility. Present mathematics placement methods include the use of ACT and SAT standardized test scores, high school record, a combination of standardized test scores and high school record, and placement exams like ACCUPLACER.

Since 2002, the University of Colorado at Denver and Health Sciences Center (UCDHSC) has required all freshmen without AP credits or completed college level courses in mathematics to take the math ACCUPLACER. Beginning with spring semester 2004, the UCDHSC mathematics department began using math ACCUPLACER scores for placement decisions in three different mathematics classes: MA 1070-Algebra for Social Sciences and Business, MA 1110-College Algebra, and MA 1401-Analytical Geometry and Calculus I.

After three semesters of using ACCUPLACER scores, it is now relevant to examine the validity and success of the current methods. This paper first explores the classical methods used by admission officers to predict academic success throughout college. Placement techniques for lower-level undergraduate classes are then discussed and placement validity is examined for two cases in the literature. Next the ACCUPLACER exam itself is analyzed along with current placement procedures at four-year institutions throughout Colorado. Finally,

UCDHSC mathematics placement techniques are discussed and correlations are developed to examine predictors of success in UCDHSC College Algebra courses. Statistical analysis is then used to analyze withdrawal rates, passing rates, and mean student grades for ACCUPLACER required classes.

Initial results show that ACCUPLACER is a statistically significant predictor of both final exam score and final course grade for MA 1110 students. Also, withdrawal rates for all three courses has statistically decreased with the use of ACCUPLACER. Mean student grades for MA 1401 students after ACCUPLACER have increased, but analysis shows no statistical difference for mean student grades of MA 1110 and MA 1070. Finally, passing rates have increased for MA 1401, but no statistical change is observed for MA 1110 and MA 1070.

2. Classical Methods for Predicting Long-Term College Success

Predicting student success has long been a question of interest for admission decisions. Counselors aim to admit students who will be successful in their chosen program and eventually attain their degree. Research suggests that the best predictor of college graduation is first year college grade point average [27]. In addition, first year grades are “the single most revealing indicator of successful adjustment to the intellectual demands of a particular college’s course of study” [10]. To aid counselors who seek predictions of first year GPA from just an application packet, researchers have analyzed the best methods for estimating first year college GPA.

Since 1980, several major studies have analyzed predictors of college success. Throughout most of the studies, five main methods are analyzed: SAT Verbal score, SAT Math Score, a combination of SAT Verbal and SAT Math score, High School Record, and a combination of SAT Verbal score, SAT Math score, and High School Record. In addition to these five cognitive predictors, non-cognitive factors such as extra-curricular activities, admission essays, and college interviews have also been researched.

In a 2001 College Board research report by Burton and Ramist, the major collegiate success studies since 1980 were grouped and analyzed. The results will be summarized according to the five main cognitive predictors of college success. Correlations for each individual study were used to determine a weighted correlation for each of the five main predictors. The results are detailed in the sections that follow.

2.1 SAT Verbal Scores

Table 2.1 summarizes the results of nine major studies conducted between 1980 and 1998. Each study examined the correlation between SAT Verbal score and undergraduate cumulative GPA [4].

Predictor	Paper	Year	# of Students	Correlation
SAT Verbal	Young & Barrett	1992	91	.17
	Shoemaker	1986	296	.21
	Shoemaker	1986	238	.23
	Crews	1993	336	.37
	Elliot & Strenta	1988	927	.38
	Moffatt	1993	28	.42
	Ra	1989	170	.42
	Young	1991	1,564	.46
	Total Students		4,155	.40

Table 2.1: Predicting Cumulative GPA From SAT Verbal Scores

A weighted average (the average of the reported correlations weighted by the number of students included in each study) gives an overall correlation of $r = .40$ between SAT Verbal scores and first year undergraduate GPA. Notice that this weighted average is highly dependent upon Young's 1991 study and the 1988 study by Elliott and Strenta. These were large studies which contributed significantly to the overall weighted average. Also of interest is the particularly low correlation of $r = .17$ associated with the Young and Barrett study of 1992. This low correlation could be attributed to the fact that only 91 students were analyzed, of which several were outliers [28].

2.2 SAT Math Scores

Table 2.2 summarizes the results of nine studies conducted between 1986 and 1993. In each study, SAT Math scores were analyzed as predictors of undergraduate GPA.

Predictor	Paper	Year	# of Students	Correlation
SAT Math	Ra	1989	170	.28
	Crews	1993	336	.31
	Elliot & Strenta	1988	927	.34
	Moffatt	1993	28	.35
	Shoemaker	1986	238	.35
	Young & Barrett	1992	91	.41
	Shoemaker	1986	296	.43
	Young	1991	1,564	.46
	Moffatt	1993	505	.49
	Total Students		4,155	.41

Table 2.2: Predicting Cumulative GPA from SAT Math Scores

A weighted average shows that for 4,155 students there is an overall correlation of $r = .41$ between SAT Math scores and GPA. Comparing these results with that of SAT Verbal scores, one can conclude that either measure will result in predictions with similar accuracy.

In recent years the ACT exam has also been extensively used, particularly in the Western United States. Preliminary analysis shows that ACT Verbal and Math scores produce similar results and correlations as the SAT [4].

2.3 SAT Verbal and SAT Math Scores

Table 2.3 summarizes results of ten major studies which analyze the combination of SAT Verbal and SAT Math scores as a predictor of college GPA. In each study, multiple regression analysis was used to determine the combination of SAT Verbal and Math scores which would produce the best predictor of student performance at each respective institution.

Notice that the weighted average produces a correlation of $r = .36$ between the SAT Verbal and Math combination and college GPA. This correlation is lower than either SAT Verbal or SAT Math alone. This occurs because the correlations are based on different samples of students and institutions. In particular, the 1992 study by Baron and Frank examined 3,816 students and only found a predictor correlation of $r = .20$. This is perhaps due to the combination of Verbal and Math score that they chose to use [2]. If the samples were comparable, the correlation for the combination of SAT Verbal and Math scores would be higher [4] and prove to be a slightly better predictor for college success than either SAT Verbal or SAT Math alone.

Predictor	Paper	Year	# of Students	Correlation
	Baron & Frank	1992	3,816	.20
	Nettles & Thoeny	1986	4,094	.31
SAT	Moffatt	1993	28	.34
Verbal	Wolf & Johnson	1995	201	.34
and	Ra	1989	170	.39
SAT	Tracey & Sedlacek	1985	1,339	.40
Math	Willingham	1985	3,442	.41
	Elliot & Strenta	1988	927	.43
	Ragosta & Braun	1991	2,473	.52
	Moffatt	1993	505	.56
	Total Students		16,995	.36

Table 2.3: Predicting Cumulative GPA From SAT Verbal & Math Scores

2.4 High School Record

Table 2.4 summarizes results from twelve major studies which compare high school record to college GPA. Each study used either cumulative high school GPA, high school class rank, or a combination of the two in order to define high school record.

From the table it can be seen that high school record has been the most studied predictor of college success. These twelve studies involved 25,175 partic-

Predictor	Paper	Year	# of Students	Correlation
	Baron & Frank	1992	3,816	.30
	Young & Barrett	1992	91	.31
	Young	1991	1,564	.35
	Wolf & Johnson	1995	201	.40
High	Elliot & Strenta	1988	927	.41
School	Nettles & Thoeny	1986	4,094	.41
Record	Shoemaker	1986	238	.41
	Ra	1989	170	.44
	Willingham	1985	3,442	.45
	Leonard & Jiang	1995	10,000	.46
	Shoemaker	1986	296	.48
	Crews	1993	336	.59
	Total Students		25,175	.42

Table 2.4: Predicting Cumulative GPA from High School Record

ipants from different ethnicities, backgrounds, geographical location, and college institution.

Overall, the weighted average signifies a correlation of $r = .42$ between high school record and undergraduate success. Notice this correlation is slightly higher than either SAT verbal or SAT math scores. Past studies have consistently shown this to be the case.

With the rise of grade inflation, the validity of using high school record alone has become a concern [23]. High school GPA is highly dependent upon which region, state, school district, and even school a student came from. As the meaning of GPA's vary between schools and more students are being categorized in the 'A' and 'B' range, admissions counselors need to combine GPA with other criteria in order to make accurate predictions.

2.5 SAT Verbal Score, SAT Math Score, and High School Record

As a result of grade inflation, most post-secondary schools have instituted a combination of high school record, SAT Verbal, and SAT Math scores for admission decisions. Table 2.5 summarizes results from five major studies in which predictors were developed from a combination of all three measures. Multiple regression was used to determine the best combination of SAT Verbal, SAT Math, and high school record at each institution.

The weighted average shows a correlation of $r = .52$ between college GPA and the combination of SAT Verbal, SAT Math, and high school record. Also of interest is that every major study had a correlation higher than any of the weighted averages for the other predictors. The results from these studies illustrate that the combination of SAT results and high school record provide the best prediction of college success.

Predictor	Paper	Year	# of Students	Correlation
SAT Verbal,	Leonard & Jiang	1995	10,000	.49
Math, and	Willingham	1985	3,442	.53
High	Ra	1989	170	.58
School	Young	1991	1,564	.58
Record	Ragosta & Braun	1991	2,473	.62
	Total Students		17,649	.52

Table 2.5: Predicting GPA From SAT Verbal, Math, & High School Record

2.6 Extra-Curricular Activities

Another factor that aids the admissions process, is the participation in extra-curricular activities. High school students are encouraged to join and participate in several extra-curricular activities to strengthen their college applications. However, research has consistently shown that participation in these activities is not a stand-alone predictor of college success.

In Willingham's study from 1985, twenty-five thousand applications were received for nine different colleges. All of the applications were examined and admissions counselors made decisions on which students would be successful at their institution. Several factors went into determining admission, including the use of high school GPA and extra-curricular activities [27].

After admission was granted, 4,814 of the students were followed through four years of college and their accomplishments were recorded. Although extra-curricular activities played a large role in determining admission, only high school GPA was determined to be a predictor of college success [27]. Likewise, in a 1994 study by Wade and Walker, honors students were tracked for two years of college. Admissions at the small southern university were dependent upon GPA, class rank, ACT scores, extra-curricular activities, and selection of honors courses. Again, high school GPA proved to be the only consistent predictor of success [24].

Finally, the Standard Research Service of the ACT program conducted a study of 10,758 college freshmen in which multiple criteria for determining college success were examined. In an attempt to predict English success, each student was evaluated based upon ACT scores, GPA, and yearbook and high school newspaper staff participation [14]. Both the ACT English score and the student's high school GPA were determined to be valid predictors of English success. However, extra-curricular activities were shown to have no real positive correlation to success in English courses [7].

Although grade point average is the most consistent predictor for success, Rice and Darke contend that extra-curricular activities are an indirect predictor of success [20]. In their 2000 study, participants were randomly selected from Leadership or Academic Scholarship students at a public university. While the researchers agreed that GPA is an accepted predictor of success, they also contend that, "the strongest addition to the traditional predictors of college success was a measure of persistent and successful extra-curricular accomplishment in high school."

2.7 Problems Associated with Predictors of College Success

Recent concern has been raised that predicting college success based upon standardized test scores and high school record alone may only provide accurate predictions for majority groups. Research indicates that traditional methods of prediction have decreased validity when applied to minority and non-traditional students and other factors need to be considered when examining their applications.

Ramist et al. [19], conducted a study on the predictive validity of SAT scores for Blacks in 11 different mainly White colleges. The researchers found a correlation of $r = .09$ between SAT and Black students' grades while there was a correlation of $r = .176$ for SAT and White students' grades. This study is one of many that have led critics to argue that the assessment provided by standardized tests is culturally and educationally inappropriate for students from racial and ethnic minority groups [4].

A difference has also been found for the predictive validity of the SAT between males and females. Burton and Ramist [4], point out that the SAT historically under-predicts the first year college performance of females and slightly over-predicts the performance of males. Many factors have been considered as possible explanations. One contribution to this difference is that males enroll in more advanced placement math and science classes in high school, leading to slightly higher SAT scores [12]. Other studies have shown that non-cognitive predictors have more influence on predictor validity for females than their male counterparts. Areas such as self-esteem, motivation, and student support were deemed more important additions to the use of standardized tests for female students and could potentially explain the SAT's historical under-prediction of female success [11].

3. Placement Techniques for Lower-Level Undergraduate Courses

In today's post-secondary environment, many students enter without the proper background necessary for successful completion of mathematics courses required for their field of study. According to the Colorado Commission of Higher Education (CCHE), 26.6% of Colorado public high school graduates (7,507 students) entering Colorado public higher education in 2002-2003 were assigned to remediation. Of the students assigned to remediation, 85.3% were assigned remediation in mathematics [6]. Therefore, proper placement and recommendation techniques play a crucial role in ensuring that students are placed in the appropriate course commensurate with their current skill level. Currently about 90% of post-secondary institutions utilize some form of placement and developmental instruction [22]. College administrations seek placement procedures that are simple, economical and defensible; while faculty seek a procedure that matches appropriate student skill with course objectives.

Although much research has been conducted on predicting college success, fewer studies analyze predictors of lower-level undergraduate mathematics success. Traditional predictors of math success have been the number of high school mathematics classes and scores on standardized tests (SAT/ACT exam). In recent years, the use of placement exams such as ACCUPLACER have also been used to determine appropriate student placement.

The following sections examine the literature on methods for predicting undergraduate mathematics success and developing predictive validity for placement techniques.

3.1 High School Coursework

The effect of high school courses on lower-level undergraduate mathematics success was studied by Roth et. al [21] in 2001. The study found that "taking more higher level math courses in high school is an accurate predictor of scoring well on aptitude tests commonly required for admission into four-year baccalaureate institutions." Even the students with average or poor grades in these high level courses were better prepared for college level work and less likely to need non-credit or remedial math. The exposure to higher level coursework helped students recognize concepts covered on the placement exams and achieve passing scores. Students who took four years of high school math were also found to be better prepared for immediate entrance into post-secondary education. The fourth year of mathematics was deemed as a bridge which links the material from high school to college [15].

3.2 SAT/ACT Scores

Standardized test scores are often used as one option for determining which students require remedial mathematics. For instance, a student with an ACT Math score of 19 or above, or an SAT Math score of 460 or above would fulfill remediation requirements set by CCHE. If post-secondary institutions use these standardized test scores for specific course placement, they are usually accompanied by an alternative cut-off score on a placement examination. This is due to research suggesting that standardized test scores are good predictors of mathematics exam scores, but are not overall predictors of success in a mathematics class. Intangible and non-cognitive factors such as desire, motivation, and peer-study have been shown to have a large effect on overall performance in the class and offset much of the correlation due to test-taking skills. These tests are still considered predictors of college success, but are becoming outdated measures to predict mathematics success; as a result standardized tests are often replaced by new placement techniques [25].

3.3 Placement Tests

Many community colleges and four-year institutions are beginning to implement placement tests as either the sole means of placement, or as an important part of the placement decision [12]. Several placement tests are available and common tests used within the U.S. include:

1. Assessment of Skills for Successful Entry and Transfer (ASSET)
2. New Jersey College Basic Skills Placement Test (NJCBSPT)
3. Mathematical Association of America Placement Test Program (MAA)
4. Descriptive Tests of Mathematical Skills (DTMS)
5. ACCUPLACER Test
6. ACT COMPASS Tests

The majority of these placement exams are actually sets of tests which include one or more components in mathematics [3]. These tests can be administered in a variety of ways. In an effort to best prepare students for college, many high schools are now administering placement exams to their graduating students the last month of school. Other placement exams are administered to students during required orientation periods before the first semester of classes. Placement exams can also be administered prior to specific courses and deemed as prerequisite requirements for successful enrollment.

3.4 Placement Exam Validity

According to the American Mathematical Association of Two-Year Colleges (AMATYC), regardless of how the placement test is administered, the main goal of testing is to determine the highest level of mathematics appropriate to students' educational goals, at which they have the prerequisite knowledge to be successful [18]. AMATYC goes on to state: "placement tests should provide a measure of students' abilities not only to show mastery of algorithmic skills, but also to think critically and solve problems."

This leads to one of the main drawbacks of placement testing; the perceived notion that capable students may be denied access to higher-level mathematics instruction at which they could have been successful. Independent studies by Armstrong [1], Jenkins [9], and Isbell [8] have all determined that a large portion of students actually succeed in mathematics classes even though their test scores labeled them as unprepared. This notion has driven research on placement validity and the development of placement techniques that avoid unfairly holding back potentially successful students.

Two recent studies have addressed the issue of developing better predictive placement techniques. Judith Marwick [12] recently completed a study at a Midwestern University which compared three alternative mathematics placement methods with the rigid placement by exam score alone. All students who took the ACCUPLACER exam during the summer of 2001 were randomly assigned to one of four placement methods: ACCUPLACER exam score alone, high school preparation alone, a balance of the two measures, or student choice constrained by the two measures [12]. The study found that overall the students performed equally well in their mathematics course regardless of which method was used for placement. When comparing placement test scores with high school record, it was determined that placement of the students would have been approximately the same regardless of which technique was used. Final recommendations show that placement by ACCUPLACER score alone denied many students access to the appropriate course in which they could have been successful. Marwick concluded that placement techniques should involve a combination of high school record and placement test score with students placed in the higher-level course recommendation.

Another ongoing study of placement technique validity has been conducted at Indiana University Purdue University Indianapolis (IUPUI). At IUPUI a computerized mathematics placement exam is used which consists of 40 objective items ranging from arithmetic operations to introductory calculus. A student's raw score is determined by the number of items answered correctly. Based on the score students are given recommendations for placement in one of three different remedial courses, or allowed to take the corresponding college course of their choice dependent on their academic major.

As students were allowed to choose whether to follow the placement recommendation, they naturally formed two separate groups for comparison, compliant and non-compliant. Predictive validity of the mathematics placement exam was then studied by analyzing the mathematics results of the two different groups.

For the compliant students who followed the placement test course recommendation, the correlation between placement score and mathematics exam score was .23. For students who did not follow placement recommendations (i.e. chose to take a more difficult course), the correlation between placement score and mathematics exam scores was .25. Also of interest is the correlation between placement test score and final course grade. For compliant students the average correlation coefficient was $r = .19$ and for non-compliant students $r = .17$.

As a result of this study, IUPUI concluded that its current placement techniques needed revision. Students who were not following placement recommendations were succeeding in higher level coursework and there was no statistical difference in the correlation between compliance and performance and non-compliance and performance. Following the study, the mathematics department switched to a Computerized Adaptive Testing (CAT) procedure much like the ACCUPLACER Exam. Preliminary results show an improvement in correlation between placement score and mathematics success; however, the non-compliant students still performed as well as the compliant students indicating that placement test scores still prevented capable students from enrolling in suitable coursework.

4. The ACCUPLACER Exam

With the help of committees of college faculty, The College Board developed the ACCUPLACER Computerized Placement Tests. These are adaptive tests that choose the difficulty of questions based on responses to previous items. There are ten different tests available which measure reading, writing, English, and mathematics ability. Within the mathematics category, three different tests are available to measure varying skill levels: the Arithmetic Test, the Elementary Algebra Test, and the College-Level Mathematics Test. Each of these tests is multiple choice with no enforced time limit.

The College-Level Mathematics Test assesses proficiency from intermediate algebra through pre-calculus. Twenty questions are asked and the topics covered include algebraic operations, solutions of equations and inequalities, coordinate geometry, applications and other algebra topics, and functions and trigonometry. The Elementary Algebra Test is twelve questions long and covers topics including operations with integers and rational numbers, operations with algebraic expressions, and solving equations, inequalities, and word problems. Finally, the Arithmetic Test consists of sixteen questions covering operations with whole numbers and fractions, operations with decimals and percents, and applications and problem solving.

ACCUPLACER utilizes Item Response Theory (IRT) to create a more efficient and individualized assessment of student mathematical skills. IRT grew out of the need to individualize assessment and adapt questions based on the skill level the student exhibits. The IRT technique that ACCUPLACER uses first creates a latent ability, θ, that can be assessed given items of known difficulty, b. IRT also includes parameters to account for item discrimination, a, and guessing, c [26]. These are combined into a 3-parameter model:

$$P(\theta) = c + \frac{1-c}{1+e^{-1.7a(\theta-b)}}$$

$P(\theta) =$ probability of respondent with ability θ to answer a question of difficulty b correctly.

$a =$ item discrimination. Proportional to the slope: $0.425a(1-c)$.

$b =$ item difficulty

$c =$ guessing parameter

$\theta =$ respondent's ability

This logistic model is referred to as an Item Characteristic Curve. Ability discrimination is theoretically maximized when $P(\theta)$ is close to the inflection point for a bank of items. If there is no guessing, this point would be around 50%. In order to ensure maximum discrimination for each item, the set of questions should differ for those of varying ability levels. In the Computerized Adaptive Test format, answering a question correctly will raise the difficulty of the next question and an incorrect response lowers the difficulty of the question that follows. This process keeps $P(\theta)$ near the curve's inflection point until θ can be estimated within an acceptable error range [26]. This procedure requires fewer questions than non-adaptive tests and can reduce both time and facilities needed to administer the exams.

There are also drawbacks of the ACCUPLACER, particularly in the Elementary Algebra Exam. The adaptive nature of the test results in large penalties for incorrect answers chosen early in the exam. If a student answers initial questions incorrectly, future questions are worth fewer points. This can lead to difficulty building up to questions of higher point value. Also, the difference between an ACCUPLACER score of 72-85 and above 85 is due to one additional correct answer. Therefore, one correct guess can effect a student's chances of achieving a cut-off score.

5. Current Placement Techniques for Colorado Colleges

Colorado law (CRS 23-1-113) requires all incoming freshmen and transfer students to be assessed for their basic skills in reading, writing, and mathematics. In order for a student to show proficiency in mathematics they must meet one of four different requirements set by CCHE. A student who achieves a score of 19 or higher on the ACT assessment mathematics exam, a score of 460 or higher on the SAT Math section, or a score of 85 or higher on the ACCUPLACER elementary algebra exam does not require remediation. In addition, if a student has successfully completed a college-level mathematics course or a remedial mathematics course, no additional assessment is necessary.

Following this May 2000 legislation, most schools throughout Colorado have implemented placement procedures for lower level mathematics courses based loosely upon remediation assessment guidelines set out by CCHE. The following gives a brief summary of placement techniques used at various colleges and universities throughout Colorado.

Adams State College

Students entering Adams State College with an ACT mathematics score of less than 19 (470 SAT mathematics score) are required to take the ACCUPLACER Elementary Algebra Test. Based on the results of that exam students are advised as follows:

1. Score of 85 or above:

   Student may enroll in Finite Mathematics or College Algebra.

2. Score of 55-84:

   Student may enroll in Intermediate Algebra.

3. Score of 40-54:

   Student may enroll in Basic Algebra Skills Class.

4. Score of 39 or lower:

   Student may enroll in Arithmetic Skills Course.

5. ACT Score of 26 or higher:

   Student may enroll in Calculus I as their first college math course. Otherwise the student must first take College Algebra before enrolling in Calculus.

Colorado Christian University

Students entering Colorado Christian University with appropriate ACT or SAT scores may enroll in the course of their choice. Students who have not taken either the ACT or SAT exam must take the math placement exam COMPASS. Based on the results of this exam the student will be advised to take remedial math or proceed with the appropriate college level course.

Colorado School of Mines (CSM)

No exams are required for students enrolled at CSM. The entry-level mathematics class for all students at CSM is Calculus I.

Colorado State University

Students who have received a score of three or above on the Advanced Placement

Calculus Exam (either AB or BC), or have transfer credit in a math course at the level of college algebra or above are not required to take any placement examinations. All other students must take the Mathematics Placement Exam (MPE). This exam consists of 50 multiple choice-multiple response questions and covers topics in College Algebra, Numerical and Analytical Trigonometry, and Logarithms and Exponential Functions. In addition, students may take the Entry Level Mathematics (ELM) Exam. This exam covers intermediate algebra topics and helps guide student choices for the entry-level mathematics courses offered at Colorado State University.

Colorado State University-Pueblo

All students are placed according to their ACT or SAT math score. If students would like to challenge the placement, they may take the ACCUPLACER Exam and attempt to receive a qualifying score.

Fort Lewis College

All students are required to take the ACCUPLACER placement exam. Each student begins with the elementary algebra exam. If a student correctly answers a certain proportion of the questions on this exam, they will then take the college-level mathematics exam. If a student does not successfully answer enough questions on the elementary algebra exam, the student is then directed to take the arithmetic exam. Based on the results of these tests, the student is advised on which course to enroll.

Metropolitan State College of Denver

Students with an ACT Math score of 19 or above or an SAT Math score of 460 or above are exempt from placement exams. All other students are required to take the ACCUPLACER Exam and must take the course corresponding to their score. The placements are as follows:

1. Score of 0-56 on the Arithmetic Exam:

   Students may take Fundamentals of Mathematics.

2. Score of 57-120 on the Arithmetic Exam:

   Students may take Pre-Algebra.

3. Score of 45-60 on the Elementary Algebra Exam:

   Students may take Introductory Algebra (a Community College of Denver (CCD) course).

4. Score of 61-84 on the Elementary Algebra Exam:

   Students may take Survey of Algebra (a CCD course).

5. Score of 85-99 on the Elementary Algebra Exam:

   Student may take any of the following: Integrated Mathematics I, Mathematical Modes of Thought, Introduction to Statistics, College Algebra with peer study, or Finite Math with peer study.

6. Score of 100-120 on the Elementary Algebra Exam:

   Student may take either College Algebra or Finite Math.

7. Score of 65-79 on the College Level Math Exam:

   Student may take Pre-Calculus.

8. Score of 80-120 on the College Level Math Exam:

   Student may take Calculus I.

University of Colorado at Colorado Springs (UCCS)

Two math placement exams are offered at UCCS. The first is the Algebra Diagnostic which measures intermediate algebra skills. Students scoring above 20 on this exam are also invited to take the Calculus Readiness Test. The scores are used for placement as follows:

1. Score of 0-8 on the Algebra Diagnostic:

   Student is required to take Fundamentals of College Algebra.

2. Score of 9-16 on the Algebra Diagnostic:

   Student may take College Algebra

3. Score of 17-19 on the Algebra Diagnostic:

   Student may take Elementary Functions of Calculus, Topics in Linear Algebra, or Calculus for Business and Economics.

4. Score of 20-32 on the Algebra Diagnostic:

   Student may take Elementary Functions of Calculus, Topics in Linear Algebra, or Calculus for Business and Economics. In addition, the student may take the Calculus Readiness Exam.

5. Score of 0-9 on the Calculus Readiness Exam:

   Student may take Elementary Functions of Calculus as preparation for Calculus I.

6. Score of 10-12 on the Calculus Readiness Exam:

   Student may take Calculus I along with the corresponding pre-calculus review offered in the math learning center.

7. Score of 13-25 on the Calculus Readiness Exam:

   Student may take Calculus I.

University of Northern Colorado (UNC)

Current placement methods at UNC are based upon orientation advising. At scheduled orientations, graduate students hold 5-10 minute advising sessions with incoming students. The students are asked a series of questions regarding their ACT/SAT math score, the mathematics courses which they took in high school, the length of time since their last mathematics course, and their intended major. Based on the information provided, the graduate students make course recommendations, however, students may register for the class of their choice.

Western State College of Colorado (WSCC)

WSCC uses a combination of ACT scores, SAT scores, and a placement exam to assess incoming students. Students are placed in the courses according to the following criteria:

1. Basic Algebra Review:

   Students may take this class regardless of their performance on the three placement techniques.

2. Mathematics for the Liberal Arts, Mathematics for the Managerial Sciences, Algebraic Functions, or Theory of Arithmetic and Geometry I:

In order to enroll in any of the above courses a student must attain a score of 19 or above on the ACT Math exam, score a 460 or above on the SAT Math exam, pass the ACCUPLACER elementary algebra test with a score of 85 or above, or pass the Basic Algebra Review class.

3. Transcendental Functions:

   A student must pass the ACCUPLACER college-level mathematics test with a score of 75 or above.

4. Probability and Statistics:

   A student must pass the ACCUPLACER college-level mathematics test with a score of 85 or above.

5. Calculus I:

   A student must pass the ACCUPLACER college-level mathematics test with a score of 95 or above.

The above sections detail placement procedures for several Colorado Colleges. It is worth noting that some colleges do not have placement requirements for all courses. This leads to an alternate way many students choose to fulfill their remediation requirement; enroll in a lower-level college course that does not mandate placement procedures. At UCDHSC there are currently no placement procedures for MA 1010-Mathematics for the Liberal Arts Student, enabling any student to enroll. A student who is in need of meeting remediation requirements during the first 30 credit hours, may take MA 1010 and fulfill the requirement. This option enables the student to gain college credit while fulfilling remediation.

6. UCDHSC Placement Techniques for Spring 2004

In Spring 2004, UCDHSC began mathematics placement procedures for all sections of MA 1110-College Algebra and MA 1070-Algebra for Social Sciences and Business. Mandatory placements were made based upon the student's performance on the ACCUPLACER Elementary Algebra Exam. For the Spring semester a passing score of 72 was required in order to continue enrollment in each class.

All students were given two opportunities to pass the ACCUPLACER Exam, with a one-day grace period required between sittings. Students who failed the exam twice could petition the Associate Chair of the Mathematics Department for a third opportunity at attaining a passing score. Elementary Algebra review sessions were available in the Math Education Resource Center (MERC) and utilized by many students. If a student did not obtain a passing score on the exam by the second week of class they were administratively dropped from the course and advised to take proper remediation to prepare them for the course.

Detailed data were recorded for all Spring 2004 College Algebra students. A database was created with the following information for each individual student: ACCUPLACER score, ACT score, SAT score, College Algebra instructor, common final exam score, and final course grade. Statistical analysis on these data had two goals:

1. Determine if statistically significant correlations exist between ACCUPLACER score, ACT score, SAT score, score on the common final exam,

and final course grade.

2. Analyze the effect of raising the cutoff score in MA 1110 from 72 to 85.

6.1 Data Description

A total of 151 students initially enrolled in College Algebra for Spring Semester 2004. Of the 151 enrolled, twelve students never took the ACCUPLACER and were administratively dropped. In addition ten students were unable to attain a score of 72 or above and were also administratively dropped. A total of 19 students achieved a passing score on the ACCUPLACER Exam, but dropped the class. Thus, the study had a sample size of 110 students who passed the ACCUPLACER exam and also finished the course.

By limitations of the data collection, ACCUPLACER scores of four students who took the course were unattainable. Also, as the majority of students in Colorado take the ACT instead of the SAT exam, the data includes ACT information for 84 students who finished the class and SAT information for only 32. Lastly, final exam scores were only available for 101 students; this indicates that nine students either did not take the common final exam or their score was unattainable in the data collection.

6.2 Correlation Among Variables

For purposes of attaining correlations, all letter grades were converted to the UCDHSC numerical equivalent shown in Table 6.1:

	A=4.0	A-=3.7
B+=3.3	B=3.0	B-=2.7
C+=2.3	C=2.0	C-=1.7
D+=1.3	D=1.0	D-=0.7
	F=0.0	

Table 6.1: Numerical Equivalent of Letter Grades

SPSS Software was used to calculate Pearson bivariate correlations among the five variables and analyze the statistical significance of each. The correlation matrix in Table 6.2 displays the results of the analysis.

From the correlation analysis, it is evident that the highest correlation occurred between ACT Math score and SAT Math score. This is not a surprising statistic for the 32 students who took both exams; research has consistently shown the two standardized tests to be highly correlated. As expected grade on the final exam and final grade in the class were also highly correlated.

One interesting aspect of this correlation analysis is that ACT Math score was determined to be a statistically significant predictor of ACCUPLACER score at the 0.01 level with a correlation of $r = .473$. However, the correlation between SAT Math score and ACCUPLACER score was not statistically significant with $r = .293$. This could be related to the smaller sample size for SAT scores which potentially caused error in the analysis.

Also, both ACT math (at the 0.01 level) and SAT math (at the 0.05 level) were considered statistically significant predictors of final exam score, but not

	ACT MATH	SAT MATH	ACCUP	Grade	Final
ACT MATH Pearson Corr.	1	.742**	.473**	.191	.328**
Sig. (2-tailed)		.000	.000	.082	.004
N	106	32	99	84	77
SAT MATH Pearson Corr.		1	.293	.159	.404*
Sig. (2-tailed)			.063	.392	.030
N		42	41	31	29
ACCUP Pearson Corr.			1	.390**	.418**
Sig. (2-tailed)				.000	.000
N			135	106	98
Grade Pearson Corr.				1	.691**
Sig. (2-tailed)					.000
N				110	101
Final Exam Pearson Corr.					1
Sig. (2-tailed)					
N					101

** Indicates the Correlation is significant at the 0.01 level (2-tailed)

* Indicates the Correlation is significant at the 0.05 level (2-tailed)

Table 6.2: Correlations for College Algebra Spring 2004

final grade in the class. Finally, there is a correlation of $r = .418$ and $r = .390$ between ACCUPLACER and final exam and final grade respectively. Both correlations are significant at the 0.01 level.

6.3 Analysis of the Results

Several conclusions can be drawn from the correlation analysis. The results support current research which attests that standardized test scores alone should not be used to predict student success in mathematics courses. Both standardized test scores were statistically significant predictors of final exam score, indicating a relationship between test-taking abilities. However, as the research suggests, standardized tests scores are not a significant predictor of final grade.

Also of interest, ACCUPLACER is a statistically significant predictor of both final exam and final grade. Therefore, course data validate the selection of ACCUPLACER as a placement technique for College Algebra students over the use of standardized tests.

6.4 Limitations of the Data

Aspects of the data set limit the strength of some results. Correlations involving SAT Math data should be interpreted with caution. Only 32 of the 110 students who took this course had SAT Math scores available, therefore the data could be biased. In addition, correlations involving ACT Math scores may also reflect bias. Although ACT information was available for 84 of the 110 students, the missing information may not be due to random effects. Often students who do not report ACT or SAT information are low-achieving students who did not plan on attending college while in high school. This could result in biased results where the excluded cases are heavily weighted with low-achieving students.

6.5 Analyzing College Algebra Cut-Off Scores

The next question of interest is whether raising the required ACCUPLACER score to 85 would significantly effect students in College Algebra. Figure 6.1 provides a graphical representation of MA 1110 Spring 2004 course data. The scatter-plot displays ACCUPLACER score as the independent variable and final grade as the dependent variable.

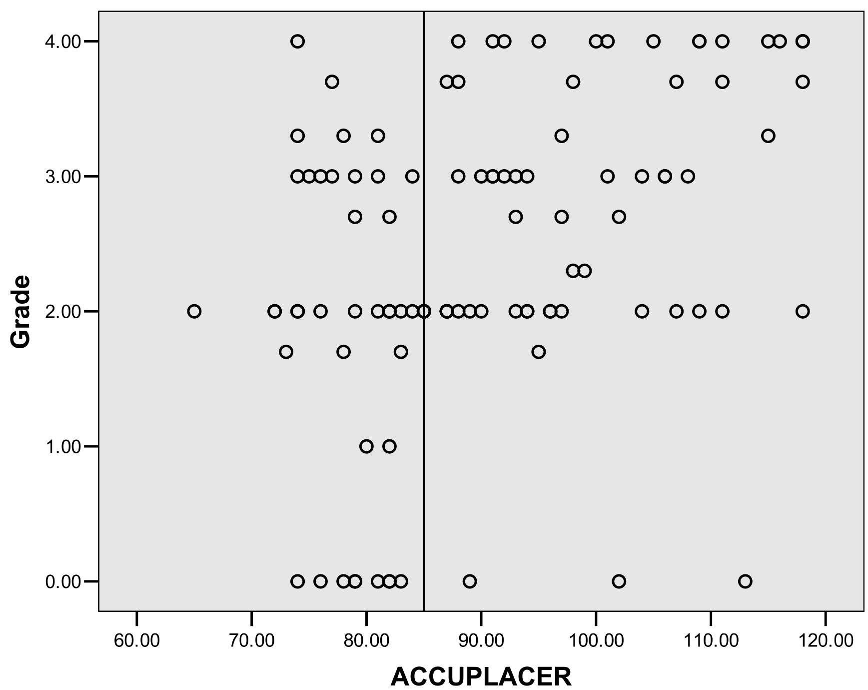

Figure 6.1: Accuplacer Versus Final Grade Spring 2004

From the graph, first note that one student took the ACCUPLACER, scored a 64, and was still able to finish the class. Following up on this student, the

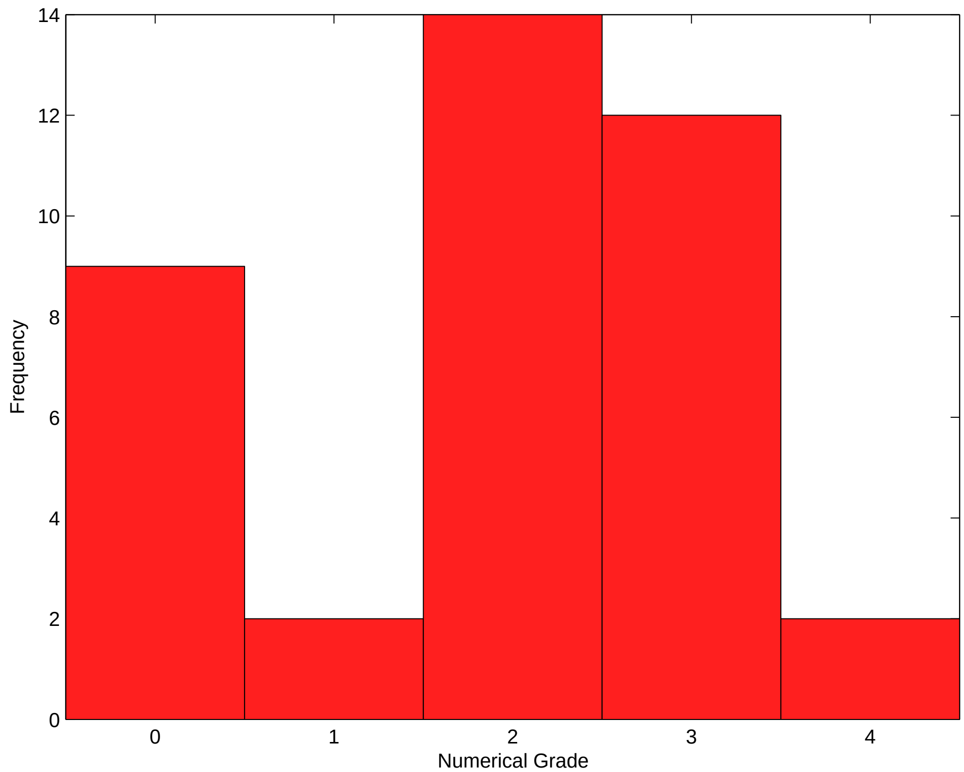

Figure 6.2: Distribution of Course Grades for Students Scoring Between 72-85

mathematics department associate chair confirmed that approximately one student slips through the cracks every other semester and is allowed to take the class without a passing ACCUPLACER score.

A total of 39 students qualified for College Algebra with an ACCUPLACER score between 72-85. Figure 6.2 shows the distribution of grades for these students.

While eleven students in this range received a D or F and did not pass the course, 28 students received a passing grade of C or above. These results can be interpreted in two ways. By examination, 72% of students scoring in the 72-85 range passed the course. This seems to indicate that the cut-off score should not be raised because capable students would be prevented from taking coursework in which they could be successful. However, many of these students achieved a score in that range on their first ACCUPLACER attempt. With attendance at an Elementary Algebra review session and pointed study, these scores could conceivably be raised to 85 or above. Also, out of the twelve students who received a failing grade of F in the course, nine fell in the 72-85 range.

In order to make accurate conclusions, students should also be tracked on whether they achieved their passing ACCUPLACER score on the first, second, or third attempt. If the majority of the students who received scores in the 72-85 range achieved their score on the first attempt, then the evidence would support raising the cut-off score to 85. After teaching Elementary Algebra review sessions and working in the MERC lab, it became apparent that students scoring above a 72 on the first attempt would most likely raise their score to the appropriate level on the next attempt. Recall that improving one's score from a 72-85 to above an 85 requires the student to answer one more question correctly on the twelve question ACCUPLACER exam.

Another factor influencing the cut-off score for College Algebra is the state requirement on remediation. As mentioned earlier, the Colorado Commission of Higher Education requires an elementary algebra score of 85 or above as one criteria for exemption from remediation. Since College Algebra is a non-remedial course, UCDHSC does not want to set its placement score lower than CCHE's remediation requirement.

6.6 MA 1110 Fall 2004 Statistics

Beginning in Fall 2004, the required ACCUPLACER score for College Algebra was raised to 85 or above. Limited data from this class providing each student's ACCUPLACER score and final course grade was available. The correlation matrix in Table 6.3 provides predictor information for ACCUPLACER versus final grade.

	ACCUPLACER	Final Grade
ACCUPLACER Pearson Corr.	1	.181*
Sig. (2-tailed)		.017
N	200	172
Final Grade Pearson Correlation		1
Sig. (2-tailed)		
N		173

* Indicates the Correlation is significant at the 0.05 level (2-tailed)

Table 6.3: Correlations for College Algebra Fall 2004

It is interesting to note that ACCUPLACER is a significant predictor of College Algebra course grades at the 0.05 level. However, the correlation coefficient of $r = .181$ is lower than any of the ACCUPLACER correlation coefficients for courses with a cut-off score of 72.

Figure 6.3 illustrates a scatter-plot for the data with ACCUPLACER score as the independent variable and final course grade as the dependent variable.

The graphical display illustrates no apparent patterns for the data collected with a cut-off score of 85 or above.

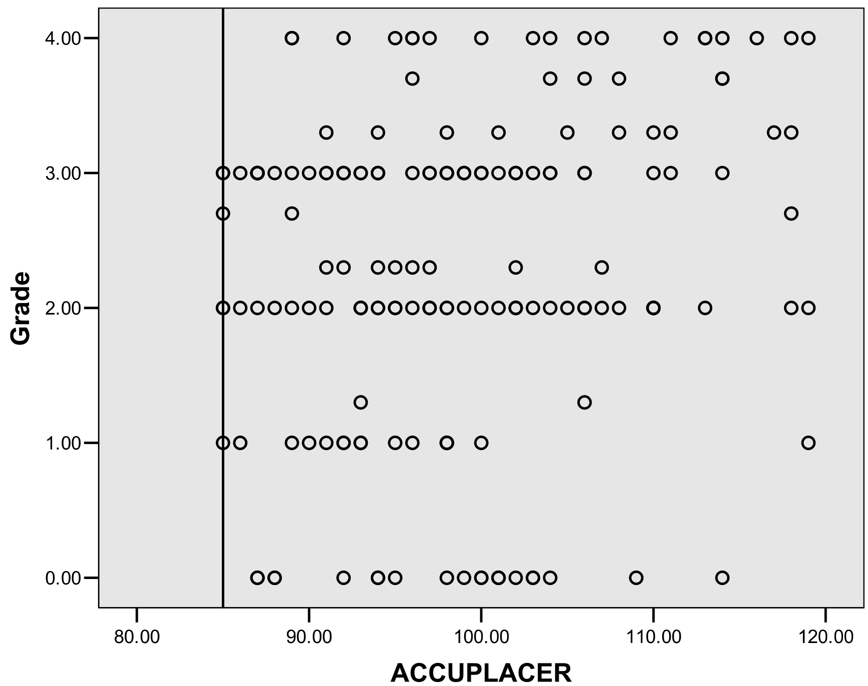

Figure 6.3: Accuplacer Versus Final Grade Fall 2004

7. Current ACCUPLACER Results

Currently UCDHSC requires passing ACCUPLACER scores for enrollment in three courses: College Algebra-MA 1110, Algebra for Social Sciences and Business-MA 1070, and Calculus I-MA 1401. To study the effects of the ACCUPLACER exam on these three courses, detailed data were provided for sections of each class from the Spring 2001 semester to Fall 2005. Each data set included distribution of individual instructor grades and number of withdrawals from each class. ACCUPLACER scores, standardized test scores, and administrative drops were not recorded in the data.

The primary goal of this study was to examine two hypotheses:

1. With the implementation of ACCUPLACER testing, there is a significant decrease in withdrawal rates for MA 1401, MA 1110, and MA 1070.

2. With the implementation of ACCUPLACER testing,there is a statistically significant increase in the mean student grades for MA 1401, MA 1110, and MA 1070.

The secondary goal of the study was to examine the hypothesis:

1. With the implementation of ACCUPLACER testing, there is an increase in passing rates for MA 1401, MA 1110, and MA 1070.

7.1 Analysis of MA 1401

Beginning in Fall 2004, students in Calculus I were required to achieve a score of 80 or above on the College Level Math portion of the ACCUPLACER exam. The data set provides detailed information for 44 sections of Calculus I before the ACCUPLACER requirements and 6 after. This corresponds to a total of 914 students before ACCUPLACER and 89 students after.

To test the hypothesis that mean withdrawal rates have decreased since the implementation of the ACCUPLACER, mean withdrawal rates were calculated for each group in the sample. Withdrawal rate is defined as the number of students in each section who withdraw from the course after Census Day with appropriate approval. Mean withdrawal rate for each group is calculated as the total number of withdrawals for each group(i.e. Before or After) divided by the number of sections.

An Independent-Samples T-Test with unequal variances was used to determine if there was a significant difference in mean withdrawal rates between classes before the ACCUPLACER and classes after. The test was set up as follows:

$\mu_1 =$ Mean withdrawal rates for MA 1401 classes before ACCUPLACER

$\mu_2 =$ Mean withdrawal rates for MA 1401 classes after ACCUPLACER

$H_0 = \mu_1 - \mu_2 = 0$

$H_a = \mu_1 - \mu_2 > 0$

Table 7.1 displays the results from the test. Withdrawal rates decreased from a mean of 3.000 student withdrawals per section before ACCUPLACER, to a mean of 1.1667 after. We conclude that at the 0.05 significance level, we reject the null hypothesis and find convincing evidence that withdrawal rates for MA 1401 are lower after the use of ACCUPLACER testing.

t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.
2.452	8.441	.038	1.83333	.74757

Table 7.1: Independent-Samples T-Test for MA 1401 Withdrawals

To test the hypothesis that mean student grades have increased since the implementation of the ACCUPLACER, the following Independent-Samples T-Test was used.

$\mu_1 =$ Mean of student grades for those who took MA 1401 before ACCUPLACER

$\mu_2 =$ Mean of students grades for those who took MA 1401 after ACCUPLACER

$H_0 = \mu_1 - \mu_2 = 0$

$H_a = \mu_1 - \mu_2 < 0$

Table 7.2 illustrates the results for the test with unequal variances. The mean student grades increased from a mean of 2.5647 before ACCUPLACER, to a mean of 2.8180 after. At the 0.05 significance level, we reject the null hypothesis and find convincing evidence that mean student grades for MA 1401 are higher after the ACCUPLACER.

t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.
-2.055	111.396	.042	-.25332	.12329

Table 7.2: Independent-Samples T-Test for MA 1401 Mean Student Grades

To further analyze the effects of ACCUPLACER, average passing rates were calculated. Passing rates are defined as the percentage of students who received an A, B, or C in the class relative to all students who finished the class. Therefore, withdrawals are not considered in the passing rate calculations. Table 7.3 details the results of this analysis.

MA 1401	Before	After
Passing Rates	81.27%	88.76%

Table 7.3: Calculus Comparisons

From the comparison in Table 7.3 passing rates increased for MA 1401 with the use of the ACCUPLACER exam. Variation in individual class sizes prevented further statistical analysis on passing rates for MA 1401.

Limitations of the data

The results for withdrawal rates should be interpreted with caution. Statistical analysis did not provide sufficient proof that the data set is normal. With only nine degrees of freedom in the data, our results may be slightly biased.

The data for mean student grades is a collection of discrete points (based on the numerical equivalence of each letter grade) and is not normal. However, because of the large sample sizes for both before and after ACCUPLACER groups, the Independent-Samples T-Test is an accurate measure.

One further limitation of the data is that the After ACCUPLACER group does not include any summer course data. This could bias the results.

7.2 Analysis of MA 1110

Beginning in Spring 2004, students in College Algebra were required to achieve a passing score on the Elementary Algebra portion of the ACCUPLACER exam. A score of 72 was considered passing for Spring and Summer 2004, and a score of 85 was considered passing for Fall 2004. The data set provides detailed information for 35 sections of College Algebra before the ACCUPLACER requirements and 15 sections after. This corresponds to a total of 858 students before ACCUPLACER and 329 students after.

We will again test the hypothesis that withdrawal rates have decreased since the implementation of the ACCUPLACER. The Independent-Samples T-Test with unequal variances was set up as follows:

$\mu_1 =$ Mean withdrawal rates for MA 1110 classes before ACCUPLACER

$\mu_2 =$ Mean withdrawal rates for MA 1110 classes after ACCUPLACER

$H_0 = \mu_1 - \mu_2 = 0$

$H_a = \mu_1 - \mu_2 > 0$

Table 7.4 displays the test results. The mean withdrawal rates decreased from a mean of 5.600 student withdrawals per section before ACCUPLACER, to a mean of 3.067 after. At the 0.01 significance level we reject the null hypothesis and find convincing evidence that withdrawal rates for MA 1110 are lower after the use of ACCUPLACER testing.

t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.
3.158	30.980	.004	2.5333	.80214

Table 7.4: Independent-Samples T-Test for MA 1110 Withdrawals

The following Independent-Samples T-Test was used to test the hypothesis that mean student grades have increased for MA 1110 after the implementation of ACCUPLACER.

$\mu_1 =$ Mean of student grades for those who took MA 1110 before ACCUPLACER

$\mu_2 =$ Mean of students grades for those who took MA 1110 after ACCUPLACER

$H_0 = \mu_1 - \mu_2 = 0$

$H_a = \mu_1 - \mu_2 < 0$

Table 7.5 shows the results for the test with unequal variances assumed. The mean student grades **decreased** from 2.4153 before ACCUPLACER to 2.3261 after.

t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.
1.103	640.130	.270	.08913	.08079

Table 7.5: Independent-Samples T-Test for MA 1110 Mean Student Grades

We can not reject the null hypothesis and there appears to be no statistical difference between mean student grades for the two groups of MA 1110 students.

Passing rates for MA 1110 were also determined. Table 7.6 details the results.

MA 1110	Before	After
Passing Rates	77.51%	79.64%

Table 7.6: College Algebra Comparisons

From the comparison in Table 7.6, passing rates slightly increased for MA 1110 after the implementation of the ACCUPLACER exam. However, the change is not significant. Limitations on the MA 1110 results are similar to those for MA 1401.

7.3 Analysis of MA 1070

Beginning in Spring 2004, students in Algebra for Social Sciences and Business (Business Algebra) were required to achieve a passing score of 72 on the Elementary Algebra portion of the ACCUPLACER exam. The data set provides detailed information for 40 sections of Business Algebra before the implementation of ACCUPLACER testing and 14 sections after. This corresponds to a total of 1103 students before ACCUPLACER and 382 after.

Analysis of withdrawal rates will again utilize an Independent Samples T-Test with unequal variances assumed and is as follows:

$\mu_1 =$ Mean withdrawal rates for MA 1070 classes before ACCUPLACER

$\mu_2 =$ Mean withdrawal rates for MA 1070 classes after ACCUPLACER

$H_0 = \mu_1 - \mu_2 = 0$

$H_a = \mu_1 - \mu_2 > 0$

Table 7.7 illustrates the test results. Mean withdrawal rates decreased from 4.500 before ACCUPLACER to 2.4286 after. We conclude that at the 0.01 significance level we reject the null hypothesis and find convincing evidence that withdrawal rates for MA 1070 are lower after the implementation of ACCUPLACER placements.

t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.
2.761	34.343	.009	2.07143	.75032

Table 7.7: Independent-Samples T-Test for MA 1070 Withdrawals

The following Independent-Samples T-Test was used to test the hypothesis that mean student grades have increased since the implementation of ACCUPLACER.

$\mu_1 =$ Mean of student grades for those who took MA 1070 before ACCUPLACER

$\mu_2 =$ Mean of students grades for those who took MA 1070 after ACCUPLACER

$H_0 = \mu_1 - \mu_2 = 0$

$H_a = \mu_1 - \mu_2 < 0$

Table 7.8 displays the results for the test with unequal variances assumed. The mean student grades **decreased** from 2.5157 before ACCUPLACER to 2.4945 after.

t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.
.277	665.219	.782	.02118	.07635

Table 7.8: Independent-Samples T-Test for MA 1070 Mean Student Grades

We can not reject the null hypothesis and there appears to be no statistical difference between mean student grades for the two groups of MA 1070 students.

Passing rates for MA 1070 are detailed in Table 7.9.

MA 1070	Before	After
Average Grade	2.389	2.38
Passing Rates	79.51%	78.27%

Table 7.9: Business Algebra Comparisons

It can be seen from Table 7.9 that passing rates slightly **decreased** for MA 1070 after the implementation of the ACCUPLACER exam, therefore showing no statistical difference. Again, limitations on the MA 1070 results are similar to those for MA 1401 and MA 1110.

8. Discussion

Hypothesis 1: Withdrawal Rates Decreased with the use of ACCUPLACER Testing

From statistical analysis it has been shown that the use of the ACCUPLACER placement exam decreased withdrawal rates in all three classes. These results may be slightly biased because of the nature of the data sets. As discussed, evidence does not suggest the data is normally distributed and the small sample size for classes sampled after the ACCUPLACER may bias the results. In addition, class data were available for only three semesters of MA 1110 and MA 1070 and only one semester of MA 1401. In order to further verify these results, future analysis should be conducted after more data are collected for all three classes.

Hypothesis 2: Mean Student Grades increased with the use of ACCUPLACER Testing

There is evidence that the mean student grades for MA 1401 have increased with the implementation of the ACCUPLACER exam. There are also limitations to this conclusion. The After ACCUPLACER group data was taken from students in Fall 2004. Future testing should involve students from Fall, Spring, and Summer to provide a more accurate representation of the sample. This conclusion is also limited by instructor variability and the hypothesis should be re-examined when future data become available.

Statistical analysis did not support the hypothesis for MA 1110 or MA 1070. Mean student grades remained approximately the same for both groups. This result is not surprising. Instructors have indicated that their grade distributions would not be altered, even with better prepared students.

Hypothesis 3: Passing Rates have increased since the use of ACCUPLACER Testing

There is evidence that passing rates have increased in MA 1401 while no change has been seen in MA 1110 and MA 1070. The results for MA 1110 and MA 1070 support the research on non-cognitive factors which play a role in student achievement. Although the students who enrolled in 1070 are theoretically better prepared for the class (because they passed ACCUPLACER), other factors such as determination, hard-work, and motivation play a role in student achievement and final course grade. Future analysis should be conducted on MA 1070 after the passing ACCUPLACER score has been raised to 85.

9. Conclusions

With the changing face of post-secondary education, placement methods play a crucial role in mathematics department operations. At the University of Colorado at Denver and Health Sciences Center, placement techniques are particularly important because of the high number of non-traditional students. Just as valid placement techniques are a necessity, evaluation of the placement process must be on-going. With the completion of three semesters of courses utilizing mandatory placement procedures, initial assessments must be made.

After analyzing course data for MA 1401, MA 1110, and MA 1070 it is clear that the use of ACCUPLACER has reduced the number of withdrawals in these courses. Also, the passing rate for MA 1401 has increased while those for MA 1110 and MA 1070 have remained relatively constant. Analysis also justifies the decision to raise the cut-off score in MA 1110 to 85 or above and the recommendation is to also raise the score in MA 1070 to 85 or above. Statistical analysis reveals that the mean of student grades increased for MA 1401 and did not change for 1110 or 1070.

Instructor reaction also provides further analysis of the ACCUPLACER placement techniques. Interviewing those who taught both before and after ACCUPLACER reveals positive feedback. Instructors report that students are better prepared for their classes and the main impact of ACCUPLACER has been to reduce the amount of time spent on review material. In addition, instructors state that course material runs smoothly with less explanation needed for past troublesome areas such as factoring and algebraic manipulation.

Concern has been raised that capable students may be excluded from taking a course in which they could be successful. Analysis of Spring 2004 College Algebra data showed that the majority of students in the 72-85 range had the ability to pass the course. However, with 2-3 opportunities to pass the exam, most of these students could feasibly raise their score to the appropriate level.

Overall, initial assessment of ACCUPLACER testing results in a favorable recommendation to continue placement procedures. This assessment should be on-going and the study should be extended with the acquisition of a few more semesters of data.

9.1 Future Analysis

Future analysis for this study would involve working with Metropolitan State College of Denver (MSCD) to analyze placement techniques. MSCD currently has one of the most extensive placement procedures in the United States and has been using placement techniques longer than UCDHSC. Access to their data could provide useful analysis with less bias due to small sample sizes.

In addition, detailed data should be collected for all three courses requiring ACCUPLACER. For every section, each individual's ACCUPLACER score, ACT Score, Final Exam Score, and Final Course Grade should be recorded. This information could provide insight into ACCUPLACER as a predictor of success in each of the three courses.

Finally, future work would also involve developing a better measure for success than final course grade. Possible alternatives are course outcomes assessment surveys and self-questionnaires administered at the end of the semester which include self descriptions of confidence in course material. These alternative measures could be useful in assessing self-described student success in each course, rather than instructor determined success.

Appendix A. Descriptive Statistics Tables

Tables A.1, A.2, and A.3 give detailed descriptive statistic information for withdrawals from MA 1401, MA 1110, and MA 1070. Tables A.4, A.5, and A.6 give detailed descriptive statistic information for student grades in the same three classes.

ACCUPLACER	Measure	Statistic	Std Error
After	Mean	1.667	.65405
After	95% Confidence Interval: Lower Bound	-.5146	
After	95% Confidence INterval: Upper Bound	2.8479	
After	5%Trimmed Mean	1.0741	
After	Median	.5000	
After	Variance	2.567	
After	Standard Deviation	1.60208	
After	Interquartile Range	2.5	
After	Skewness	1.354	
After	Kurtosis	1.240	1.741
Before	Mean	3.00	.36205
Before	95% Confidence Interval: Lower Bound	2.2699	
Before	95% Confidence Interval: Upper Bound	3.7301	
Before	5% Trimmed Mean	2.8434	
Before	Median	2.00	
Before	Variance	5.767	
Before	Standard Deviation	2.40155	
Before	Interquartile Range	4	
Before	Skewness	.865	.357
Before	Kurtosis	.219	.702

Table A.1: Descriptive Statistics for MA 1401 Withdrawals

ACCUPLACER	Measure	Statistic	Std Error
After	Mean	3.0667	.63596
After	95% Confidence Interval: Lower Bound	1.7027	
After	95% Confidence INterval: Upper Bound	4.4307	
After	5%Trimmed Mean	2.9630	
After	Median	2.000	
After	Variance	6.067	
After	Standard Deviation	2.46306	
After	Interquartile Range	4.00	
After	Skewness	.541	.580
After	Kurtosis	-.770	1.121
Before	Mean	5.6000	.48887
Before	95% Confidence Interval: Lower Bound	4.6065	
Before	95% Confidence Interval: Upper Bound	6.5935	
Before	5% Trimmed Mean	5.6111	
Before	Median	5.00	
Before	Variance	8.365	
Before	Standard Deviation	2.89218	
Before	Interquartile Range	5.00	
Before	Skewness	.177	.398
Before	Kurtosis	-.975	.778

Table A.2: Descriptive Statistics for MA 1110 Withdrawals

ACCUPLACER	Measure	Statistic	Std Error
After	Mean	2.4286	.56173
After	95% Confidence Interval: Lower Bound	1.2150	
After	95% Confidence INterval: Upper Bound	3.6421	
After	5%Trimmed Mean	2.3651	
After	Median	1.500	
After	Variance	4.418	
After	Standard Deviation	2.10180	
After	Interquartile Range	4.00	
After	Skewness	.552	.597
After	Kurtosis	-1.393	1.154
Before	Mean	4.500	.49743
Before	95% Confidence Interval: Lower Bound	3.4939	
Before	95% Confidence Interval: Upper Bound	5.5061	
Before	5% Trimmed Mean	4.3889	
Before	Median	3.00	
Before	Variance	9.897	
Before	Standard Deviation	3.14602	
Before	Interquartile Range	5.75	
Before	Skewness	.718	.374
Before	Kurtosis	-.840	.733

Table A.3: Descriptive Statistics for MA 1070 Withdrawals

ACCUPLACER	Measure	Statistic	Std Error
After	Mean	2.8180	.11619
After	95% Confidence Interval: Lower Bound	2.5871	
After	95% Confidence INterval: Upper Bound	3.0489	
After	5%Trimmed Mean	2.9089	
After	Median	3.00	
After	Variance	1.201	
After	Standard Deviation	1.09613	
After	Interquartile Range	1.70	
After	Skewness	-1.118	.255
After	Kurtosis	.847	.506
Before	Mean	2.5647	.04124
Before	95% Confidence Interval: Lower Bound	2.4837	
Before	95% Confidence Interval: Upper Bound	2.6456	
Before	5% Trimmed Mean	2.6274	
Before	Median	3.00	
Before	Variance	1.554	
Before	Standard Deviation	1.24672	
Before	Interquartile Range	1.70	
Before	Skewness	-.666	.081
Before	Kurtosis	-.517	.162

Table A.4: Descriptive Statistics for MA 1401 Student Grades

ACCUPLACER	Measure	Statistic	Std Error
After	Mean	2.3261	.06709
After	95% Confidence Interval: Lower Bound	2.1942	
After	95% Confidence INterval: Upper Bound	2.4581	
After	5%Trimmed Mean	2.3624	
After	Median	2.300	
After	Variance	1.481	
After	Standard Deviation	1.21695	
After	Interquartile Range	1.00	
After	Skewness	-.566	.134
After	Kurtosis	-.514	.268
Before	Mean	2.4153	.04502
Before	95% Confidence Interval: Lower Bound	2.3269	
Before	95% Confidence Interval: Upper Bound	2.5036	
Before	5% Trimmed Mean	2.4614	
Before	Median	2.700	
Before	Variance	1.739	
Before	Standard Deviation	1.31857	
Before	Interquartile Range	1.60	
Before	Skewness	-.567	.083
Before	Kurtosis	-.783	.167

Table A.5: Descriptive Statistics for MA 1110 Student Grades

ACCUPLACER	Measure	Statistic	Std Error
After	Mean	2.4945	.06574
After	95% Confidence Interval: Lower Bound	2.3652	
After	95% Confidence INterval: Upper Bound	2.6238	
After	5%Trimmed Mean	2.5494	
After	Median	3.00	
After	Variance	1.651	
After	Standard Deviation	1.28492	
After	Interquartile Range	1.70	
After	Skewness	-.656	.125
After	Kurtosis	-.624	.249
Before	Mean	2.5157	.03883
Before	95% Confidence Interval: Lower Bound	2.4395	
Before	95% Confidence Interval: Upper Bound	2.5919	
Before	5% Trimmed Mean	2.5730	
Before	Median	3.00	
Before	Variance	1.663	
Before	Standard Deviation	1.28963	
Before	Interquartile Range	1.70	
Before	Skewness	-.634	.074
Before	Kurtosis	-.634	.147

Table A.6: Descriptive Statistics for MA 1070 Student Grades

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