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An Analysis of Final Course Grades in Two Different Entry Level Mathematics Courses Between and Among First Year College Students with Different Levels of High School Mathematics Preparation

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AN ANALYSIS OF FINAL COURSE GRADES IN TWO DIFFERENT ENTRY LEVEL MATHEMATICS COURSES BETWEEN AND AMONG FIRST YEAR COLLEGE STUDENTS WITH DIFFERENT LEVELS OF HIGH SCHOOL MATHEMATICS PREPARATION

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The purpose of this study was to compare the performance of first year college students with similar high school mathematics backgrounds in two introductory level college mathematics courses, *Fundamentals and Techniques of College Algebra* and *Quantitative Reasoning and Mathematical Skills,* and to compare the performance of students with differing high school mathematics backgrounds within each course. High school mathematics backgrounds were considered in three forms: using the binary minimum preparation standards of the college, using levels defined by the preparation standards and high school academic data, and using levels defined only by high school academic data. Performance in the two college courses was considered through two different measures: final grades for students who completed their courses, and a binary measure of course success determined by whether a student completed the course with a

grade of C- or above. Statistical tests of correlation, independence of variables, and difference of means were used to analyze the data.

The minimum preparation standards were found to have no significant relation to final grade or course performance. Levels of preparation defined by high school data and minimum preparation standards were also found to have no significant relation to final grade or course performance. Levels of preparation defined only by high school data showed no significant relation to course success, but showed a positive relation to final course grade.

For students with below or above average levels of high school preparation, as measured by either non-binary scale, there was no significant difference in student performance between the two courses, while students with average levels of high school preparation performed significantly better in the Quantitative Reasoning course than in the Algebra course. For first year students in general, there was no difference in mean final grade between the two courses considered, but rates of success were higher in the Quantitative Reasoning course than in the Algebra course.

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Chapter 1

Introduction

In 1996, Richard Sawyer stated, "Most American postsecondary institutions have course placement systems for their first-year students." In 2003, the percentage of post-secondary institutions using some form of placement testing was estimated to be 90 percent (Zimmaro, 2003). For new students entering the University of Colorado at Boulder, there has been a survey-based course suggestion tool for first-year level writing classes: students answer questions about their self-perception of their writing skills, their high school course background, and their level of comfort with writing assignments, and are then given a suggestion for their first writing course. New students have also been able to choose to take skills-based placement tests for several foreign languages; after taking one of these placement tests, a student is given both his test score and the suggested course for beginning college coursework in the relevant foreign language. There has, however, been no placement program for mathematics.

Anyone wishing to implement a mathematics placement program at the University of Colorado at Boulder will face challenges related to the freshmen admissions process and the structure of general education requirements. There are currently six colleges and schools at the University of Colorado at Boulder which offer undergraduate degrees: the College of Architecture and Planning, the College of Arts and Sciences, the Leeds School of Business, the College of Engineering and Applied

Science, the School of Journalism and Mass Communication, and the College of Music. Each college and school has its own admissions policies, and each has its own general education requirements. However, a student enrolled in one college or school may transfer to another, and requirements for a college or school can be fulfilled by courses taken in a different college or school (University of Colorado at Boulder, 2010).

New students can apply for direct admission to any college or school except Journalism and Mass Communication. The majority of students apply to Arts & Sciences (University of Colorado at Boulder, 2011b); students who apply to, but are not accepted for, the other colleges and schools are automatically reconsidered for acceptance to Arts & Sciences (University of Colorado at Boulder, 2010). Thus, the minimum admissions requirements for the College of Arts & Sciences serve, by default, as the minimum admissions standards for the campus. The Minimum Academic Preparation Standards (MAPS) for Arts & Sciences include four years of mathematics, including two years of algebra, one year of geometry, and one year "of college preparatory math such as trigonometry, analytic geometry, or elementary functions" (University of Colorado at Boulder, 2010, p. 8). A student who has successfully completed at least four years of high school mathematics which included levels of coursework higher than those described are considered to have met the standard; a student who has successfully completed less than four years of high school mathematics has not met the standard, regardless of the level of coursework completed.

Students who are admitted without having met the requirements for a MAPS category are said to have a *MAPS deficiency*. MAPS deficiencies are to be filled by taking college-level (non-remedial) coursework. Based on administrative interpretation of Colorado statutes, the University of Colorado at Boulder cannot offer remedial coursework to prepare students with MAPS deficiencies for such college-level coursework (Colorado Department of Education, 2004, §4.02.01).

All undergraduate students in the College of Engineering and Applied Science are required to pass at least two semesters of calculus; this requirement can be met either by two semesters of the Analytic Geometry and Calculus sequence, taught by the Department of Mathematics, or by two semesters of the Calculus for Engineers sequence, taught by the Department of Applied Mathematics. Students in the College of Music have no mathematics requirement. Students in all other colleges and schools must fulfill a Quantitative Reasoning requirement, choosing from up to 20 courses taught by six different departments; exact course options vary slightly by college or school (University of Colorado at Boulder, 2010).

Because of the variety of calculus and quantitative reasoning courses available to freshmen at the University of Colorado at Boulder, students who are not in need of remedial coursework are able to choose from multiple courses which match their backgrounds. Student in need of remedial coursework have no courses to choose from which match their background, but have several courses at the same introductory level to choose from. In order to develop a mathematics placement program, then, it is necessary to be able to accurately place students in the correct level of course, and then allow the students to select the most appropriate course at that level. In order for such a program to be developed, it must be known whether courses which are intended to require the same level of student background and experience are equally challenging to students with similar backgrounds.

This study considers the two courses taught by the Department of Mathematics which are considered to be at the most basic, introductory level: MATH 1011 *Fundamentals and Techniques of College Algebra* and MATH 1012 *Quantitative Reasoning and Mathematical Skills*. Students were divided into groups based on their levels of preparation. Students who have a MAPS deficiency in mathematics formed the first group. The students who have met the MAPS requirement were then divided into groups based on: whether they have taken more than the minimum high school coursework to fulfill the MAPS requirement; overall GPA in high school mathematics courses; score on the ACT or SAT mathematics subtest. High school preparation levels were also considered on a scale independent of the MAPS requirement.

Purpose of the Study

The purpose of this study was to compare the performance of populations of first year college students with similar high school mathematics backgrounds in the courses MATH 1011 and MATH 1012, and to compare the performance of populations of students with differing high school mathematics backgrounds within each of the courses MATH 1011 and MATH 1012.

Research Questions

1. Was there a significant difference in final course grades or course success for MATH 1011 between the populations of students with and without MAPS deficiencies in mathematics?

2. Across all first year students, was there a significant difference in final course grades or course success in MATH 1011 between groups with different levels of high school preparation? Alternatively, to what extent is there a relationship between preparation level and final course grades or course success in MATH 1011?

3. Was there a significant difference in final course grades or course success for MATH 1012 between the populations of students with and without MAPS deficiencies in mathematics?

4. Across all first year students, was there a significant difference in final course grades or course success in MATH 1012 between groups with different levels of high school preparation? Alternatively, to what extent is there a relationship between preparation level and final course grades or course success in MATH 1012?

5. For students with MAPS deficiencies in mathematics, was there a significant difference in final course grades or course success between MATH 1011 and MATH 1012?
6. For students without MAPS deficiencies in mathematics, was there a significant difference in final course grades or course success between MATH 1011 and MATH 1012?
7. For students with similar levels of high school preparation, was there a significant difference in final course grades or course success between MATH 1011 and MATH 1012?
8. For all students, to what extent is there a relationship between final course grade or course success and whether the student took MATH 1011 or MATH 1012?
9. To what extent is there a relationship between whether or not a student has MAPS deficiencies in mathematics and final course grades or course success for the combined population of students in MATH 1011 or MATH 1012?
10. To what extent is there a relationship between preparation level and final course grades or course success for the combined population of students in MATH 1011 or MATH 1012?

Assumptions

For this study, it was assumed that the offices of Admissions and Orientation correctly identified all students considered first year college students. It was also assumed that no significant revisions to course content or pedagogy was made to the courses being examined during the period of Fall 2009 to Fall 2011.

Delimitations

There were sections of MATH 1011 and MATH 1012 which were run by units other than the Department of Mathematics in the Fall 2009, Fall 2010, and Fall 2011 semesters; these units included the Student Academic Services Center, the Residence Halls, the Division of Continuing Education and Professional Studies, and the Honors Program. Because the exact content and pedagogy for those sections was largely outside the control of the Department of Mathematics, and some of these sections were specifically designed for limited, selective student sub-populations, those sections are not included in this study.

Limitations

This study only considered first year college students who are recent United States high school graduates and are taking a mathematics course during their first semester in college. The study has a relatively small sample size, $n = 119$.

Definition of Terms

The following terms are defined for this dissertation.

Course success: A student who completed a course with a grade of C- or above was considered successful; a student who withdrew

	from the course, or earned a grade below C-, was considered unsuccessful.
First year student:	A student who has not taken college coursework since graduating from high school and who graduated from high school within the previous year.
ISIS:	The Integrated Student Information System, the online records system used by the University of Colorado system. Includes the Singularity document imaging and management system.
Level 0:	Students who had a MAPS deficiency in mathematics.
Level 1:	Students who did not have a MAPS deficiency in mathematics, but who were below average in their overall high school mathematics background, as measured by high school mathematics courses taken, GPA in high school mathematics courses, and mathematics sub-score on the SAT or ACT entrance exam.
Level 2:	Students who did not have a MAPS deficiency in mathematics, and who were average in their overall high school mathematics background, as measured by high school mathematics courses taken, GPA in high school mathematics

courses, and mathematics sub-score on the SAT or ACT entrance exam.

Level 3: Students who did not have a MAPS deficiency in mathematics, and who were above average in their overall high school mathematics background, as measured by high school mathematics courses taken, GPA in high school mathematics courses, and mathematics sub-score on the SAT or ACT entrance exam.

MAPS: The Minimum Academic Preparation Standards for the University of Colorado at Boulder. First year students are expected, but not required, to have met these standards through high school coursework. The MAPS requirement for mathematics is four years of high school coursework, all at the level of algebra and geometry or above.

MAPS deficiency: A student who begins coursework at the University of Colorado at Boulder, without having fulfilled a MAPS category is said to have a MAPS deficiency.

MATH 1011: Sections of the course MATH 1011 *Fundamentals and Techniques of College Algebra* taught by the Department of Mathematics at the University of Colorado at Boulder.

MATH 1012: Sections of the course MATH 1012 *Quantitative Reasoning and Mathematical Skills* taught by the Department of Mathematics at the University of Colorado at Boulder.

Stratum 1: Students who were below average in their overall high school mathematics background, as measured by high school mathematics courses taken, GPA in high school mathematics courses, and mathematics sub-score on the SAT or ACT entrance exam.

Stratum 2: Students who were average in their overall high school mathematics background, as measured by high school mathematics courses taken, GPA in high school mathematics courses, and mathematics sub-score on the SAT or ACT entrance exam.

Stratum 3: Students who were above average in their overall high school mathematics background, as measured by high school mathematics courses taken, GPA in high school mathematics courses, and mathematics sub-score on the SAT or ACT entrance exam.

Significance of the Study

While there was a significant body of research examining the placement of students into remedial mathematics coursework, there was no comparable body of research examining students who had been determined to be in need of mathematics remediation, but did not have the opportunity to take remedial level courses. Similarly, while there was a significant body of research examining student performance in introductory level (non-remedial) college mathematics courses in the context of only a single such course being available, there was no comparable body of research examining student performance in the context of multiple introductory level (non-remedial) college mathematics courses, designed for students who intend to follow different academic tracks. Unlike other studies, this study compared populations of students considered to be in need of remediation and those not considered to be in need of remediation in the context of a university which does not offer remedial courses, but which does offer more than one introductory level college mathematics course.

Chapter 2

Literature Review

The Purpose of Placement

Students planning to take a first semester college calculus course come from a wide variety of backgrounds. Students should have access to information which allows them to decide whether or not they are prepared to take such a course. Providing students with this information before they register for classes should: improve overall student success in first semester calculus, allow students to plan the most efficient and effective degree program, and increase student persistence in calculus-dependent programs.

To improve their chances of success, students with inadequate preparation for particular courses should be identified so that they can be steered towards the appropriate resources, whether a preparatory course, study skills seminar, or some other assistance (Ahmadi & Raiszadeh, 1990; Goonatilake & Chappa, 2010). Inadequately prepared students, even those who work very hard at a course, have holes in their understanding of course material; those holes build up, prevent understanding of subsequent material, leading to frustration for both students and instructors, as well as course failure for the students (Kennedy, 1990).

Studies have shown that students benefit from having, and following, placement guidance for mathematics courses (Palmer, 1987; Rounds & Anderson, 1985). Students who follow placement recommendations for mathematics complete their mathematics courses at a substantially higher rate than those who do not follow such a recommendations (Felder, Finney, & Kirst, 2007). In addition, students who are under a system of mandatory placement for remedial work have a higher graduation rate than students under a voluntary placement system (Lepley, 1993).

The research on the influence, if any, course placement has on student persistence and retention has shown mixed results (Bahr, 2010; Goonatilake & Chappa, 2010; Hern, 2010; Jaggars & Hodara, 2011). One study found that students who successfully completed a remedial course had an impressive 90 percent retention rate (Chand, 1984) and another study found that for students who were underprepared for college-level coursework, taking a remedial course during the first year was a positive indicator of persistence (Campbell & Blakey, 1995). However, another study found that students who were exempted from remedial coursework or who completed suggested remedial coursework had no higher of a retention rate than students who did not take the remedial coursework that was suggested for them (Pierson, 1993).

Remediation Issues

Many placement studies have focused on the very real problem of students entering college without the necessary knowledge and skills to succeed in college-level coursework (Bragg, 2011; Hern, 2010; Jaggars & Hodara, 2011). As of 1993, 74 percent of United States post-secondary schools offered some kind of coursework which was considered remedial, and 68 percent of United States post-secondary schools offered remedial mathematics courses (Economics and Statistics Administration of the United States Department of Commerce, 1993). According to the report “Diploma to Nowhere” (Strong American Schools, 2008), 34 percent of all undergraduate college students have taken at least one remedial course. While some of the students in remedial classes are adults beginning or returning to college after a long absence from schooling, many are traditional freshmen and transfer students: the Strong American Schools (2008) study also reports that in the year 2000, 28 percent of all entering college freshmen were enrolled in remedial coursework (Strong American Schools, 2008). The problem of students in need of remediation is particularly widespread in the two-year community colleges, which tend to have open enrollment policies and available remedial coursework (Bragg, 2011; Cohen & Brawer, 1989; Jenkins & Cho, 2012; Kennedy, 1990; Krol, 1993; McTarnaghan, 1987; Morante, 1987; Perry, Bahr, Rosin, & Woodward, 2010). As a natural result, much of the research regarding placement into remedial or college-level courses has been done in and by the community colleges. This research emphasized determining whether or not students need remedial work, or proper placement into a hierarchy of first-year mathematics courses ranging from remedial level to precalculus courses (Akst & Hirsch, 1991; Armstrong, A.G., 1999; Armstrong, W.B., 1994; Cullinane & Treisman, 2010; Jaggars & Hodara, 2011; Perry et al., 2010). However, interpreting the research is complicated by a lack of consistency within higher education regarding what constitutes college-level work, as opposed to remedial- or developmental-level work (Abraham, 1992; Cullinane & Treisman, 2010).

Placement Programs

Since World War II, college mathematics placement strategies have focused on first-year college students, and have generally been based on placement test scores or other measures of student skills and knowledge (Morante, 1987; Nagarkatte, 1988). Through the 1950s, most post-secondary institutions used mandatory placement systems; in the 1960s and 1970s, voluntary placement was the most common system; since the 1980s, colleges have been returning to mandatory placement systems (Bragg, 2011; Carter, 1991; Cohen, 1985; Mathematical Association of America, 1990; Morante, 1987; Palmer, 1987; Rounds & Anderson, 1985; Truman, 1982). The return to mandatory placement may well be influenced by the fact that, as the number and diversity of students enrolled in college calculus courses grew during the 1970s and 1980s, the percentage of students who failed college calculus courses also grew (Bressoud, 2004; Krawczyk & Toubassi, 1999). Voluntary programs also have difficulties not only with getting student to pay attention to placement suggestions (Jaggars & Hodara, 2011), but with getting students to participate in the process: Britton, Daners, and Stewart (2007) found that when an optional placement test was made available online to entering college students, very few actually took the test before enrolling in courses, or even before the beginning of the term.

Whether utilization of a placement recommendation is mandatory or voluntary, there are two main approaches to determining the recommended placement (Jenkins, 1990). One is a conservative approach: cutoff scores on the placement instruments are set high, so that students on the cusp are placed into a lower level course. This approach has the advantage of increased levels of student success in the recommended course (Jenkins, 1990; Palmer, 1987). However, because it errs on the side of underplacing students, this approach can lead to students being bored in the recommended course and having doubts about the accuracy of placement (Aldridge & DeLucia, 1989; Perry et al., 2010). Underplacement can also lead to students taking more courses than necessary, increasing the time and cost of their degree programs (Culbertson, 1997; Hern, 2010; Jaggars & Hodara, 2011; Jenkins & Cho, 2012).

The second approach is more liberal: cutoff scores on the placement instruments are set low, so that students on the cusp are placed into higher level courses. This approach minimizes the risks of boredom and unnecessarily extending a student's degree program, but has high course failure rates and is associated with low rates of student persistence (Jaggars & Hodara, 2011; Jenkins, 1990; Johnson, 1993; Palmer, 1987).

Because no single variable is truly predictive of collegiate mathematics success (Culbertson, 1997; Eshenroder, 1987; Ingalls, 2008), many authors have suggested or studied multivariate approaches to placement (Armstrong, W. B., 2000; Bassarear, 1991; Bone, 1981; Bridgeman & Wendler, 1991; Culbertson, 1997; Edwards, 1972; Green, 1990; McTarnaghan, 1987). Armstrong (2000) found that to explain variance in student outcomes, he needed to include in his model not only placement test scores and student background information, but also information about instructor grading practices. His findings underscore the importance of consistent grading across multiple sections of courses, both for accurate student placement and equitable student success. (Armstrong, W. B., 2000).

Any weaknesses in an institution's placement program can be compounded by the fact that the academic advisors who help students in making course selections are generally no more comfortable with mathematics than their students (Hassett, Downs, & Jenkins, 1992; Muir, 2006). Because the advisors are not able to discuss students' mathematics backgrounds and abilities in any depth, nor to offer their own informed opinions on students' mathematics course placement, they must rely completely on the placement recommendation (Hassett, Downs, & Jenkins, 1992).

Types of Data

The majority of studies regarding prediction of student success in higher education have used a range of measures as independent or predictive variables. These variables can be roughly categorized as follows (Bone, 1981; Culbertson, 1997; Geltz, 2009; Helmick, 1983; Ingalls, 2008; Jenkins, 1990):

- National standardized aptitude and placements tests (e.g. SAT, ACT, AccuPlacer) or focused subtests (e.g. SAT-M, ACT-M).

- Locally developed placement tests
- High school academic measures (e.g. overall GPA, mathematics coursework taken, mathematics grade point average). For transfer students, prior collegiate performance might also be considered in this category.
- Student demographic descriptors
- Measures of student effort in and commitment to the course
- Measurements of student self-perceptions and beliefs about mathematics ability, mathematics interest, general academic skills, intended major, etc.

National standardized tests

There have been many studies which examined the use of nationally standardized tests for mathematics course placement, but with mixed results (Jaggars & Hodara, 2011). Some of these studies have shown that factors such as ACT-M or SAT-M scores are significant in explaining variance in final exam scores and final course grades in entry-level mathematics classes (Green, 1990; Lovering, 1989; Siegel, Galassi, & Ware, 1985). Others studies have shown that the predictive value of such scores varies proportionally with the level of mathematics course taken (Case, 1983; Pines, 1981), or that these scores have little predictive value at all (Benbow & Arjmand, 1990; Berenson, Best, Stiff, & Wasik, 1990; Berenson, Carter, & Norwood, 1992; Gougeon, 1985). Neither the ACT/SAT nor ACT-M/SAT-M were able to differentiate between different levels of students with remediation needs (Morante, 1987).

When examining the full ACT and SAT tests, the findings have consistently shown them to be strong predictive variables for success in mathematics classes, but only to the same extent that they are predictive of overall college success (Wainer & Steinberg, 1992). Because tests such as the ACT and SAT were designed to be general aptitude measures, they are weak predictors of success in college mathematics classes compared to instruments designed for placement purposes (Bridgeman & Wedler, 1989; Dorner & Hutton, 2002; Ingalls, 2008 Zimmaro, 2003).

Locally developed placement tests

Locally developed placement tests can improve access and convenience for students. While nationally standardized tests must be given under rigorously defined and proctored conditions, and can often only be offered at set dates and times, locally developed tests can be made available to students online and on demand (Felder, Finney, & Kirst, 2007). The use of locally developed placement tests over nationally standardized placement tests, such as COMPASS or AccuPlacer, can also provide significant cost reductions to the institution (Felder, Finney, & Kirst, 2007).

In addition to simple convenience, there are two main assumptions behind institutional preference for the use of course specific placement tests over existing student data in mathematics placement systems. The first is that, for any mathematics course, there is a well defined set of prerequisite skills and knowledge, and that an exam designed specifically to test for those prerequisites is the best indicator of course readiness (Felder, Finney, & Kirst, 2007; Hills, Hirsch, & Subhiyah, 1990; Pomplun, 1991; Whitcomb, 2002). The second is that high school academic measures, such as mathematics courses completed or overall grade point average, are inherently inconsistent and therefore unreliable (Ang & Noble, 1993; Hills, Hirsch, & Subhiyah, 1990; Noble, 1991; Smittle, 1995; Whitcomb, 2002). High schools are not consistent in their grading systems or standards (Morante, 1987). While most use a four-point system, some use a weighted system and others do not (Zirkel, 1999). High school data would also not give a current picture of the skills and knowledge of non-traditional students (Morante, 1987). Based on these two assumptions, a third implicit assumption is that placement test scores have higher predictive validity for college mathematics success than any available student data.

The second and third assumptions have been fairly well studied, and do not hold up to examination. There was little or no significant difference in the ability of high school grade point averages (mathematics specific and overall) and placement test scores to predict final grades in college mathematics courses (Noble & Sawyer, 1987; Pomplun, 1991; Sawyer, 1989; Smittle, 1995; Whitcomb, 2002).

Academic background

Lovering (1989) studied 17 student background variables as possible predictors of grades in an introductory college mathematics course; of the 17, high school graduation class rank was the best predictor variable. Pines (1981) found that significant predictor variables for student success in college mathematics courses were overall high school grade point average, high school mathematics grade point average, number of mathematics classes taken in high school, and SAT-M score. Newman (1994) found that both high school class rank and high school GPA to be strong predictor variables for success in an introductory college-level algebra course. Several other studies found overall high school grade point average to be a significant predictor variable for college mathematics success (Berenson, Carter, & Norwood, 1992; Buchalter & Stephens, 1989; Dykes, 1980; Edwards, 1972; Hood, 1992; Noble & Sawyer, 1989; Tompkins, 1993).

In Bridgeman and Wendler's study (1991), high school grade point average (HS GPA) and SAT-M score were the strongest predictor variables. HS GPA was the first variable to enter the equation in seven of nine different university sample groups, and explained an average of eight percent of total variance in mathematics course success. SAT-M was the first variable to enter in only one of the nine groups, but was the second variable to enter the equation in the remaining eight groups. SAT-M also explained an average of 4 percent of total variance in mathematics course success (Bridgeman & Wendler, 1991). Edwards (1972) and Berenson, Carter, and Norwood (1992) both found that HS GPA was the most significant predictor variable for mathematics success, with locally constructed mathematics placement tests the second most significant variable.

Demographics

Studies since the 1980s have indicated that there is now little difference in mathematical performance between male and female students with similar academic backgrounds (Friedman, 1989; Hyde, Fennema, & Lamon, 1990). Differences were found between the genders in testing strategies, which led to differences in placement test scores (Anderson, 1989). Gender was also associated with the number and difficulty level of mathematics courses which students chose to take in college, as well as with choice of major field of study. (Boli, Allen, & Payne, 1985; Hackett, et al, 1992; Helmick, 1983; Pines, 1981; Porter, 1986; Siegel, et al., 1985; Stage & Kloosterman, 1991).

Ethnicity was found to be predictive of initial success in college, including mathematics success. (Ahmadi & Raiszadeh, 1990; Goonatilake & Chappa, 2010, Hood, 1992; Taube & Taube, 1991). However, ethnicity was not a predictor of academic persistence, overall college success, or long-term mathematics success (Anderson & Darkenwald, 1979; Travis, 1994).

Despite concerns about non-traditional students time away from school putting them at a disadvantage, age was not a predictive variable for student persistence, mathematics achievement, or overall college performance (Buchalter & Stephens, 1989; Elliott, 1990; Johnson, 1993; Owens, 1986; Taube & Taube, 1991; Wilder, 1991). However, the predictor variables for mathematics achievement were different for traditional and non-traditional aged students: the best predictors for the non-traditional students were their feelings about school and mathematics (Barker, 1994; Bershinsky, 1993).

Student effort and commitment

Anthony (2000) found that both students and instructors believed that student self-motivation was an important factor in student success in first-year college mathematics courses. She also found that students saw the effect of their own behaviors, such as class attendance and note taking, on their course success or failure (Anthony, 2000). Callahan (1993) found that students placed into College Algebra by the Cottey College placement tests had a 55 percent success rate. However, when only students who regularly attended class were considered, the success rate rose to 75 percent (Callahan, 1993).

Affective variables

In general, affective variables, such as attitude towards mathematics, mathematics self-efficacy and academic self-concept were predictive of overall college success, but had little or no significance as predictors of mathematics achievement (Aiken, 1961; Bershinsky, 1993; Bessant, 1995; Buchanan, 1992; Eldersveld & Baughman, 1986; Elliott, 1990; Geradi, 1990; Hackett & Betz, 1989; McCausland & Stewart, 1974).

Results of studies relating mathematics anxiety and mathematics achievement have been decidedly mixed. Several studies found that there was little or no correlation between mathematics anxiety and success in college mathematics coursework (Llabre & Suarez, 1985; Wilder, 1991). However, Hembree's (1990) meta-analysis of 13 studies found a connection between particularly high levels of mathematics anxiety and particularly low performance in college mathematics courses. Other studies found links between mathematics anxiety and other factors which were predictive of mathematics achievement, such as number of mathematics courses taken in high school and general measures of mathematics preparation (Betz, 1978; Green, 1990).

Test Validation and Consequence Issues

According to Hassett, Downs, and Jenkins (1992), in order for student success rates to be improved by the use of a single test score for placement, the correlation between test score and final class grade would need to be $r \geq 0.80$. Bone (1981) considered at success rate of 70 percent to be "a reasonable goal for mathematics placement."

The most commonly used measure of placement system effectiveness is the predictive validity coefficient, used to measure the correlation between the placement measurement or prediction and some measure of course performance (Baldwin, Bensimon, Dowd, & Kleiman, 2011; Bone, 1981; Noble & Sawyer, 1995; Sawyer, 1989). California's community colleges are even required to produce evidence of criterion-related validity for any placement test used (Cage, 1991). However, the validity coefficient is not useful for setting cutoff scores, nor does it take into account any matters of implementation (Belfield & Crosta, 2012; Bridgeman, Hale, Lewis, Pollack, & Wang, 1992). Predictive validity coefficients have also been criticized for what Whitcomb (2002) calls their “lack of inherent meaning” and the “difficulty with translating predictive validity coefficients into meaningful placement indices.” (Noble & Sawyer, 1995; Whitcomb, 2002). Armstrong (2000) observes that, “for both theoretical and technical reasons the predictive validity coefficients between placement test scores and final grades or retention in a course generally demonstrate a weak relationship.” Felder, Finney, and Kirst (2007) noted that while placement programs can help make sure that students start at the appropriate level course, there are many other variables which affect final course success.

Two alternate measures of placement system effectiveness seem to have grown in popularity among researchers: these measures are sometimes referred to as the *success rate* and the *accuracy rate* (Belfield & Crosta, 2012; Crocker & Algina, 1986; Ingalls, 2008; Noble & Sawyer, 1995; Sawyer, 1989; Scott-Clayton, 2012; Whitcomb, 2002). If we assume a setting where all students are measured by the placement instrument and all students consequently enroll in a course, then Whitcomb (2002) describes these two measures as follows: “Success rate refers to the percentage of successful students in the course who have scores above the hypothetical cutoff score that is being considered for entrance into that course," and, "Accuracy rate refers to the percentage of overall accurate placements that would be made when using the hypothetical cutoff to place students in the course or its . . . prerequisite."

It is common, in practice, for a placement system to be put into use before the system has been tested or validated in any way (Airasian, 1989; Ang & Noble, 1993; Belfield & Crosta, 2012; Noble & Sawyer, 1987). Available data or a locally developed placement test are used to provide at least enrollment guidance, and possibly mandatory placement, based on the implicit assumption that there is some degree of validity to the system. If the placement system is then measured by predictive validity coefficient for success in student placement, the validation study is susceptible to the problem of "prior selection" (Noble & Sawyer, 1995; Whitcomb 2002).

Culbertson (1997) pointed out that their are inconsistencies between achievement or placement tests and classroom exams. While course exams generally require students to show all work and allow for partial credit, the achievement and placement exams are multiple choice, with full credit for the correct answer and no credit for the incorrect answer. When Culbertson was writing, the achievement and placement tests generally did not allow for calculator usage, while in class exams often did. Many nationally standardized tests now allow the use of calculators, but not all courses do.

Chapter 3

Research Methodology

Subjects

This study used data collected from the records of students at the University of Colorado at Boulder. The study subjects were first year college students who had graduated from high school in the United States and who were enrolled in a section of either MATH 1011 or MATH 1012 which was taught by the Department of Mathematics in the Fall 2009, Fall 2010, or Fall 2011 semester.

Data Collection

All data used in this study was information which was already collected on each student in the Integrated Student Information System (ISIS), either as a part of the process of admissions to the University of Colorado at Boulder or as a part of the student's University of Colorado transcript.

The majority of the data for this study was collected by the University of Colorado at Boulder's Office of Institutional Research and Analysis. That office determined which students enrolled in relevant sections of MATH 1011 or MATH 1012 during the three semesters in question were first year college students who graduated from a high school in the United States. For each identified subject, Institutional Research and Analysis then provided the following information: an anonymized Student ID; the term in which the student was a first year college student; the course (MATH

1011 or MATH 1012) taken from the Mathematics Department during that semester; the course section in which the student was enrolled; the grade the student earned in the course, including *W* grades for students who withdrew after the initial drop deadline and *I* grades for students who took grades of incomplete; the student's highest score on the mathematics subtest of the ACT, if taken; the student's highest score on the mathematics subtest of the SAT, if taken; the number of years of high school algebra successfully completed by the student; the number of years of high school geometry successfully completed by the student; the number of years of high school precalculus, trigonometry, analysis, analytic geometry, statistics, discrete mathematics, or finite mathematics successfully completed by the student; and the number of years of high school calculus successfully completed by the student. The data set provided by the Office of Institution Research and Analysis contained information on 726 students.

The Office of Institutional Research and Analysis was unable to perform an automatic collection to pull the identified subjects' high school grades in mathematics courses; high school transcripts are scanned and stored electronically, and units of coursework in different categories are recorded, but high school course grades are never recorded. The Director of Institutional Analysis gave permission for the author to use her existing access to student records to identify the subject students and collect data on grades in high school mathematics courses, provided no identifiable student information was recorded in any form at any step of the identification or collection. In order to comply with these security and privacy provisions, transcripts could only be viewed for a sample of the subject group: those whose high school transcripts could be found, viewed, and read within the document management system, without the transcript being downloaded for viewing. The resultant sample size was 119.

In order to ensure that the sample whose high school mathematics GPA could be calculated was representative of the overall subject group, the following tests were performed. To determine whether the proportion of students enrolled in each course did not differ significantly for the sample compared to the subject group, a χ^2 goodness of fit test was performed; there was no significant difference, with $\chi^2(1,119) = 0.01$, $p = 0.92$. To determine whether the three semesters under considerations were represented in similar proportions in the subject group and sample, a χ^2 goodness of fit test was performed; there was no significant difference, with $\chi^2(2,119) = 0.43$, $p = 0.81$. To determine whether the proportion of students who successfully completed their course with a grade of C- or better was similar for the subject group and sample, a χ^2 goodness of fit test was performed; there was no significant difference, with $\chi^2(1,119) = 0.24$, $p = 0.63$. To determine whether the mean grade for the sample differed significantly from the mean grade for the subject group from which the sample was drawn, a single sample t test was performed; there was no significant difference, with $t(112) = -0.69$, $p = 0.49$. To determine whether the proportion of students with MAPS deficiencies was similar for the sample and the subject group, a χ^2 goodness of fit test was performed; there was no significant difference, with $\chi^2(1,119) = 3.19$, $p = 0.07$. To determine whether the mean standardized mathematics subject test score, as measured by *z*-score, for the sample differed significantly from the mean score for the subject group from which the sample was drawn, a single sample *t* test was performed; there was no significant difference, with $t(118) = 0.97$, $p = 0.33$. Finally, to determine whether the three semesters under consideration were represented in similar proportions in the sample and in the subject group, a χ^2 goodness of fit test was performed; there was no significant difference, with $\chi^2(3,119) = 2.69$, $p = 0.44$.

Variables

Dependent variable

The dependent variable in this study was the student's grade in either MATH 1011 or MATH 1012. The grades earned in the courses were one of the following: A, A-, B+, B, B-, C+, C, C-, D+, D, D-, F, W, or I. A grade of W is assigned to any student who withdraws from a course after the 12th class day of a semester. A grade of I denotes that the student has not completed the course, and must either do so within one year's time or be assigned an F grade. Students who received I grades were not considered in this study.

Grades other than W or I were recorded as point values defined by the University of Colorado system: $\text{A} = 4.0$, $\text{A-} = 3.7$, $\text{B+} = 3.3$, $\text{B} = 3.0$, $\text{B-} = 2.7$, $\text{C+} = 2.3$, $\text{C} = 2.0$, $\text{C-} = 1.7$, $\text{D+} = 1.3$, $\text{D} = 1.0$, $\text{D-} = 0.7$, $\text{F} = 0$. Successful students were defined as those who completed the course with a grade of C- or above. The dependent variable was noted in two forms.

1. SUCCESS: grade of C- or above = 1, grade of D+ or below or of W = 0
2. GRADE: grade of W not included, all other grades = defined grade points

Independent variables

The independent variables were considered in this study were as follows.

1. CUCOURSE: mathematics course taken during the student's first semester at the University of Colorado at Boulder; $\text{MATH } 1011 = 1$, $\text{MATH } 1012 = 2$.
2. MAPS: whether or not a student had a MAPS deficiency in mathematics; $\text{MAPS} = 0$ for a student with a MAPS deficiency, $\text{MAPS} = 1$ otherwise.
3. MATHMAX: the highest level of mathematics course successfully completed in high school; calculus courses = 3, precalculus, trigonometry, analysis, statistics and finite or discrete mathematics courses = 2, geometry and second year algebra courses = 1, first year algebra courses and pre-algebra courses = 0.
4. MATHYRS: number of years of mathematics coursework completed in high school with grades of C- or above; each semester of a mathematics course = 0.5 year.
5. MATHGPA: grade point average in high school mathematics coursework.

6. STDMATH: score on the mathematics subtest of the ACT or SAT college admissions test; raw scores were converted to z-scores based on the mean and standard deviations reported in the Digest of Education Statistics (National Center for Education Statistics, 2011); for the ACT mathematics subtest, $\mu = 21$ and $\sigma = 5.3$; for the SAT mathematics subtest, $\mu = 516$ and $\sigma = 116$. If a student had more than one reported score, the highest z-score was used.

7. LEVEL: level of high school mathematics preparation, determined by MAPS, MATHMAX, MATHYRS, MATHGPA, and STDMATH. See Table 1 and Figure 1 for full definitions. LEVEL = 1 was defined to be students who were below average in high school mathematics preparation, but who did not have MAPS deficiencies; however, no such students appeared in the sample. LEVEL = 0 includes all students with MAPS deficiencies in mathematics, aligning with the practice of considering MAPS deficient students unprepared for college level mathematics coursework.

8. STRAT: level of high school preparation, determined by MATHMAX, MATHYRS, MATHGPA, and STDMATH. These levels were referred to as *strata*, to differentiate from the variable LEVEL, and were defined

independently of MAPS status. See Table 2 and Figure 2 for full definitions.

Data Analysis

For comparisons of relative frequencies and for tests of independence of variables, Pearson's χ^2 test was used whenever possible; where expected cell values were smaller than five, or where any cell value was zero, Fisher's exact test was used. For two sample analysis of difference of means, independent sample Student's *t*-tests were used; *F*-tests were first performed to determine whether the difference in variances for the samples was significant, and the results of the *F*-test was then used to determine whether the *t*-test should assume equal or unequal variances. For three sample analysis of difference of means, one-way, independent sample analysis of variance was used. When differences of means were compared using *t*-tests for unequal variances or using analysis of variance, the difference of means test was followed by a test of correlation or association; Pearson's correlation coefficient, Spearman's rank correlation coefficient, and the point-biserial coefficient of association were used, depending on the variables being examined. Finally, multivariate analyses for main effects and interactions were performed using two-way, correlated samples analysis of variance.

Table 1

Criteria for Levels of High School Preparation

	Level of Preparation			
	MAPS deficient	not MAPS deficient		
Variable	Below Average	Below Average	Average	Above Average
MATHMAX	≤ 1	N/A	2	3
MATHYRS	<4	N/A	4	>4
MATHGPA	N/A	≤ 2.3	>2.3 and ≤ 3.3	>3.3
STDMATH	N/A	<-1	≥ -1 and ≤ 1	>1

Figure 1

Definitions of Levels of High School Preparation

0 points assigned for each criteria in which a student was below average, 1 point for each criteria in which a student was average, and 2 points for each criteria in which a student was above average.

Level 0: Student had a MAPS deficiency

Level 1: Student had no MAPS deficiency, was assigned less than 3 points

Level 2 Student had no MAPS deficiency, and was assigned between 3 and five points (inclusive)

Level 3: Student had no MAPS deficiency, and was assigned more than five points

Table 2

Criteria for Strata of High School Preparation

Variable	Level of Preparation		
	Below Average	Average	Above Average
MATHMAX	≤ 1	2	3
MATHYRS	<4	4	>4
MATHGPA	≤ 2.3	>2.3 and ≤ 3.3	>3.3
STDMATH	<-1	≥ -1 and ≤ 1	>1

Figure 2

Definitions of Strata of High School Preparation

0 points assigned for each criteria in which a student was below average, 1 point for each criteria in which a student was average, and 2 points for each criteria in which a student was above average.

Stratum 1: Student was assigned less than 3 points

Stratum 2: Student was assigned between 3 and five points (inclusive)

Stratum 3: Student was assigned more than five points

Chapter 4

Analysis and Results

Initial Conditions

To determine whether students with MAPS deficiencies in mathematics were represented in MATH 1011 and MATH 1012 in similar proportions, Pearson's χ^2 test was applied. The variables CUCOURSE and MAPS were found to be independent and the representation of students with MAPS deficiencies equivalent, $\chi^2\left(1,119\right) = 0.23$, $p = 0.63$. Pearson's χ^2 test was also used to determine CUCOURSE and LEVEL are independent variables, $\chi^2\left(2,119\right) = 5.17$, $p = 0.08$. Fisher's exact test was used to determine CUCOURSE and STRAT are independent variables, $p = 0.07$.

Research Question 1

Was there a significant difference in final course grades or course success for MATH 1011 between the populations of students with and without MAPS deficiencies in mathematics?

Analysis

The sample contained 44 students students enrolled in MATH 1011. Ten of those students had MAPS deficiencies in mathematics and 34 did not. Three of the 44 students had W grades, and so were excluded from assessments based on GRADE; none of the students who withdrew had MAPS deficiencies.

An independent Student's t-test for difference of means was conducted to determine whether there was a significant difference in final course grades for MATH 1011 between the students with and without MAPS deficiencies in mathematics. An F-test for the significance of the difference between the variances of the two samples, MAPS = 0 and MAPS =1, was performed. $F(9,30) = 1.02$ and $p = 0.45$, so the Student's t-test used an assumption of equal variances. The sample showed no significant difference in final course grades for MATH 1011 between the students with and without MAPS deficiencies in mathematics, $t(39) = -0.60$, $p = 0.55$.

To determine whether there was a significant difference in course success for MATH 1011 between the students with and without MAPS deficiencies in mathematics, Fisher's exact test was applied. The sample showed no significant difference in course success, $p = 0.45$.

Conclusions

There was no significant difference in final course grades or course success for MATH 1011 between the populations of students with and without MAPS deficiencies in mathematics.

Research Question 2

Across all first year students, was there a significant difference in final course grades or course success in MATH 1011 between groups with different levels of high school preparation? Alternatively, to what extent is there a relationship between preparation level and final course grades or course success in MATH 1011?

Analysis

The sample contained 44 students students enrolled in MATH 1011. Ten of those students had MAPS deficiencies in mathematics and 34 did not. Three of the 44 students had W grades, and so were excluded from assessments based on GRADE; none of the students who withdrew had MAPS deficiencies.

To determine whether there was a significant difference in final course grades in MATH 1011 between groups with different levels of high school preparation, an independent samples one-way analysis of variance for difference of means was conducted. The sample showed no significant effect for high school preparation level on final grades in MATH 1011, $F\left(2,38\right) = 1.37$, $p = 0.27$.

The extent of relationship between high school preparation level and final course grade in MATH 1011 was also examined by finding the Spearman's rank correlation coefficient for the independent variables LEVEL and GRADE. There was no significant correlation of the variables, $r_s = 0.27$, $t\left(39\right) = 1.74$, $p = 0.09$.

To determine whether there was a significant difference in course success in MATH 1011 between groups with different levels of high school preparation, Fisher's exact test was applied. The sample showed no significant dependence between course success and high school preparation level, $p = 0.76$.

The extent of relationship between high school preparation level and course success in MATH 1011 was also examined by finding the point-biserial coefficient of association for the independent variables LEVEL and SUCCESS. There was no significant association of the variables, $r_{pb} = 0.04$, $t(42) = 0.25$, $p = 0.80$.

To determine whether there was a significant difference in final course grades in MATH 1011 between groups with different strata of high school preparation, an independent samples one-way analysis of variance for difference of means was conducted. The sample showed no significant effect for high school preparation strata on final grades in MATH 1011, $F(2,38) = 3.08$, $p = 0.06$.

The extent of relationship between high school preparation strata and final course grade in MATH 1011 was also examined by finding the Spearman's rank correlation coefficient for the independent variables STRAT and GRADE. There was significant correlation of the variables, $r_s = 0.41$, $t(39) = 2.82$, $p = 0.01$.

To determine whether there was a significant difference in course success in MATH 1011 between groups with different strata of high school preparation, Fisher's exact test was applied. The sample showed no significant dependence between course success and high school preparation strata, $p = 0.12$.

The extent of relationship between high school preparation strata and course success in MATH 1011 was also examined by finding the point-biserial coefficient of association for the independent variables STRAT and SUCCESS. There was no significant association of the variables, $r_{pb} = 0.25$, $t(42) = 1.70$, $p = 0.10$.

Conclusions

For all students enrolled in MATH 1011, there was no significant difference in final course grades or course success between groups with different levels of high school preparation. There was no relationship between preparation level and either final course grades or course success. These results were not affected by whether or not the measure of course preparation is contingent on MAPS deficiency status.

Research Question 3

Was there a significant difference in final course grades or course success for MATH 1012 between the populations of students with and without MAPS deficiencies in mathematics?

Analysis

The sample contained 75 students enrolled in MATH 1012. Twenty of those students had MAPS deficiencies in mathematics and 55 did not. Three of the 75 students had W grades, and so were excluded from assessments based on the variable GRADE; none of the students who withdrew had MAPS deficiencies.

An independent Student's *t*-test for difference of means was conducted to determine whether there was a significant difference in final course grades for MATH 1012 between the students with and without MAPS deficiencies in mathematics. An *F*-

test for the significance of the difference between the variances of the two samples, MAPS = 0 and MAPS =1, was performed. $F(19,51) = 1.63$ and $p = 0.08$, so the Student's t-test used an assumption of equal variances. The sample showed no significant difference in final course grades for MATH 1012 between the students with and without MAPS deficiencies in mathematics, $t(70) = -1.37$, $p = 0.18$.

To determine whether there was a significant difference in course success for MATH 1012 between the students with and without MAPS deficiencies in mathematics, Fisher's exact test was applied. The sample showed no significant difference in course success, $p = 0.24$.

Conclusions

There was no significant difference in final course grades or course success for MATH 1012 between the populations of students with and without MAPS deficiencies in mathematics.

Research Question 4

Across all first year students, was there a significant difference in final course grades or course success in MATH 1012 between groups with different levels of high school preparation? Alternatively, to what extent is there a relationship between preparation level and final course grades or course success in MATH 1012?

Analysis

The sample contained 75 students enrolled in MATH 1012. Twenty of those students had MAPS deficiencies in mathematics and 55 did not. Three of the 75 students had W grades, and so were excluded from assessments based on the variable GRADE; none of the students who withdrew had MAPS deficiencies.

To determine whether there was a significant difference in final course grades in MATH 1012 between groups with different levels of high school preparation, an independent samples one-way analysis of variance for difference of means was conducted. The sample showed no significant effect for high school preparation level on final grades in MATH 1012, $F(2,69) = 1.22$, $p = 0.30$.

The extent of relationship between high school preparation level and final course grade in MATH 1012 was also examined by finding the Spearman's rank correlation coefficient for the independent variables LEVEL and GRADE. There was no significant correlation of the variables, $r_s = 0.16$, $t(70) = 1.36$, $p = 0.18$.

To determine whether there was a significant difference in course success in MATH 1012 between groups with different levels of high school preparation, Fisher's exact test was applied. The sample showed no significant dependence between course success and high school preparation level, $p = 0.43$.

The extent of relationship between high school preparation level and course success in MATH 1012 was also examined by finding the point-biserial coefficient of association for the independent variables LEVEL and SUCCESS. There was no significant association of the variables, $r_{pb} = 0.17$, $t(73) = 1.44$, $p = 0.15$.

To determine whether there was a significant difference in final course grades in MATH 1012 between groups with different strata of high school preparation, an independent samples one-way analysis of variance for difference of means was conducted. The sample showed no significant effect for high school preparation strata on final grades in MATH 1012, $F(2,69) = 2.68$, $p = 0.08$.

The extent of relationship between high school preparation strata and final course grade in MATH 1012 was also examined by finding the Spearman's rank correlation coefficient for the independent variables STRAT and GRADE. There no was significant correlation of the variables, $r_s = 0.21$, $t(70) = 1.82$, $p = 0.07$.

To determine whether there was a significant difference in course success in MATH 1012 between groups with different strata of high school preparation, Fisher's exact test was applied. The sample showed no significant dependence between course success and high school preparation strata, $p = 0.32$.

The extent of relationship between high school preparation strata and course success in MATH 1012 was also examined by finding the point-biserial coefficient of association for the independent variables STRAT and SUCCESS. There was no significant association of the variables, $r_{pb} = 0.19$, $t(73) = 1.61$, $p = 0.11$.

Conclusions

For all students enrolled in MATH 1012, there was no significant difference in final course grades or course success between groups with different levels of high school preparation. There was no relationship between preparation level and either final course grades or course success. These results were not affected by whether or not the measure of course preparation is contingent on MAPS deficiency status.

Research Question 5

For students with MAPS deficiencies in mathematics, was there a significant difference in final course grades or course success between MATH 1011 and MATH 1012?

Analysis

The sample contained 30 students with MAPS deficiencies. Ten of those students were enrolled in MATH 1011 and 20 were enrolled in MATH 1012. None of the students in the sample who had MAPS deficiencies withdrew from their course.

An independent Student's t-test for difference of means was conducted to determine whether there was a significant difference in final course grades between MATH 1011 and MATH 1012 for students with MAPS deficiencies in mathematics. An F-test for the significance of the difference between the variances of the two samples, CUCOURSE = 1 and CUCOURSE = 2, was performed. $F(9,19) = 1.60$ and $p = 0.19$, so the Student's t-test used an assumption of equal variances. The sample showed no significant difference in final grades for students with MAPS deficiencies between those who were enrolled in MATH 1011 and those who were enrolled in MATH 1012, $t(28) = -0.86$, $p = 0.40$.

To determine whether there was a significant difference in the course success of students with MAPS deficiencies in mathematics between the students who were enrolled in MATH 1011 and those who were enrolled in MATH 1012, Fisher's exact test was applied. The sample showed no significant difference in course success, $p = 0.66$.

Conclusions

For students with MAPS deficiencies in mathematics, there was no significant difference in final course grades or course success between MATH 1011 and MATH 1012.

Research Question 6

For students without MAPS deficiencies in mathematics, was there a significant difference in final course grades or course success between MATH 1011 and MATH 1012?

Analysis

The sample contained 89 students without MAPS deficiencies. Thirty-four of those students were enrolled in MATH 1011 and 55 were enrolled in MATH 1012. Six of the 89 students had W grades, and so were excluded from assessments based on the variable GRADE; those six students were evenly divided in enrollment in MATH 1011 and MATH 1012.

An independent Student's t-test for difference of means was conducted to determine whether there was a significant difference in final course grades between MATH 1011 and MATH 1012 for students without MAPS deficiencies in mathematics. An F-test for the significance of the difference between the variances of the two samples, CUCOURSE = 1 and CUCOURSE = 2, was performed. $F\left(30,51\right) = 2.55$ and $p < 0.01$, so the Student's t-test used an assumption of unequal variances. The sample showed no significant difference in final grades for students with MAPS deficiencies between those who were enrolled in MATH 1011 and those who were enrolled in MATH 1012, $t\left(44.22\right) = -1.64$, $p = 0.11$.

The extent of relationship between course selection and final course grade for students without MAPS deficiencies was also examined by finding the point-biserial coefficient of association for the independent variables CUCOURSE and GRADE. The sample showed no significant association of the variables, $r_{pb} = 0.20$, $t\left(81\right) = 1.81$, $p = 0.07$.

To determine whether there was a significant difference in the course success of students without MAPS deficiencies in mathematics between the students who were enrolled in MATH 1011 and those who were enrolled in MATH 1012, Fisher's exact test was applied. The difference in rates of success for students without MAPS deficiencies in mathematics, 68% for MATH 1011 and 91% for MATH 1012, was found to be significant, $p = 0.01$.

Conclusions

While there was no significant difference in course grades between MATH 1011 and MATH 1012 for students without MAPS deficiencies in mathematics, there was a significant difference in rates of course success for those students. Students without MAPS deficiencies in mathematics were more successful in MATH 1012 than in MATH 1011.

Research Question 7

For students with similar levels of high school preparation, was there a significant difference in final course grades or course success between MATH 1011 and MATH 1012?

Analysis

Different levels of preparation, MAPS taken into consideration

Of the 119 students in the sample, 30 were categorized as Level 0, 73 were categorized as Level 2, and 16 were categorized as Level 3. There were no students in the sample without MAPS deficiencies in mathematics who were also of below average high school mathematics preparation, so Level 1 was not represented in the sample. Six of the 119 students had W grades, and so were excluded from assessments based on GRADE; all six of these students were categorized as Level 2. See Table 3 for a detailed breakdown of the students in the the sample by level and course.

Table 3

Distribution of Sample by Level and Course

	Course		
Preparation Level	MATH 1011	MATH 1012	Total
MAPS Deficient	10	20	30
Average	24	49	73
Above Average	10	6	16
Total	44	75	

For each of the three levels, an independent Student's *t*-test for difference of means was conducted to determine whether there was a significant difference in final course grades between MATH 1011 and MATH 1012 for students within the level. *F*-tests for the significance of the difference between the variance of the samples, CUCOURSE = 1 and CUCOURSE = 2, were performed for each level.

For Level 0, $F(9,19) = 1.60$ and $p = 0.19$, so the Student's *t*-test used an assumption of equal variances. For Level 2, $F(20,45) = 1.72$ and $p = 0.07$, so the Student's *t*-test used an assumption of equal variances. For Level 3, $F(9,5) = 19.19$ and $p < 0.01$, so the Student's *t*-test used an assumption of unequal variances. The results of the *t*-tests are summarized in Table 4. The sample showed no significant difference in final grades between MATH 1011 and MATH 1012 for students with below average or above average levels of high school preparation. For students with average levels of high school preparation, the mean grades of 2.10 for MATH 1011 and 2.91 for MATH 1012 were found to be significantly different.

Table 4

Difference of Mean Grades Between Courses by Preparation Level

	Preparation Level		
	MAPS Deficient	Average	Above Average
df	28	65	10.49
t	-0.86	-2.55	-0.33
p	0.40	0.01	0.75

For each level, Fisher's exact test was applied to determine whether there was a significant difference in the course success between the students who were enrolled in MATH 1011 and those who were enrolled in MATH 1012. The results of these tests are summarized in Table 5. For students with either above or below average levels of high school preparation, the sample showed no significant difference in rates of course success between the two courses. For students with average levels of high school preparation, the difference in rates of success, 63% for MATH 1011 and 90% for MATH 1012, was found to be significant.

Table 5

Difference in Rates of Success Between Courses by Preparation Level

	Preparation Level		
	MAPS Deficient	Average	Above Average
p	0.66	0.01	0.50

Different strata of preparation, MAPS not taken into consideration

Of the 119 students in the sample, 9 were categorized as Stratum 1, 94 were categorized as Stratum 2, and 16 were categorized as Stratum 3. Six of the 119 students had W grades, and so were excluded from assessments based on GRADE; all six of these students were categorized as Stratum 2. See Table 6 for a detailed breakdown of the students in the the sample by stratum and course.

Table 6

Distribution of Sample by Stratum and Course

	Course		
Preparation Stratum	MATH 1011	MATH 1012	Total
Below Average	2	7	9
Average	32	62	94
Above Average	10	6	16
Total	44	75	

For each of the three strata, an independent Student's t-test for difference of means was conducted to determine whether there was a significant difference in final course grades between MATH 1011 and MATH 1012 for students within the stratum. F-tests for the significance of the difference between the variance of the samples, CUCOURSE = 1 and CUCOURSE = 2, were performed for each stratum. For Stratum 1, $F(6,1) = 4.78$ and $p = 0.33$, so the Student's t-test used an assumption of equal variances. For Stratum 2, $F(28,58) = 1.72$ and $p = 0.04$, so the Student's t-test used an assumption of unequal variances. For Stratum 3, $F(9,5) = 19.19$ and $p < 0.01$, so the Student's t-test used an assumption of unequal variances. The results of the t-tests are summarized in Table 7. The sample showed no significant difference in final grades between MATH 1011 and MATH 1012 for students with below average or above average high school preparation. For students with average high school preparation, the mean grades of 2.20 for MATH 1011 and 2.75 for MATH 1012 were found to be significantly different.

Table 7

Difference of Mean Grades Between Courses by Stratum

	Preparation Level		
	Below Average	Average	Above Average
df	7	44.54	10.49
t	-1.66	-2.24	-0.33
p	0.14	0.03	0.75

For each strata, Fisher's exact test was applied to determine whether there was a significant difference in the course success between the students who were enrolled in MATH 1011 and those who were enrolled in MATH 1012. The results of these tests are summarized in Table 8. For students with either above or below average high school preparation, the sample showed no significant difference in rates of course success between the two courses. For students with average high school preparation, the difference in rates of success, 69% for MATH 1011 and 89% for MATH 1012, was found to be significant.

Table 8

Difference in Rates of Success Between Courses by Stratum

	Preparation Level		
	Below Average	Average	Above Average
p	0.17	0.02	0.50

Conclusions

For students with below average or above average levels of high school preparation, there was no significant difference in either final course grades or course success between MATH 1011 and MATH 1012. These results were not affected by whether or not the measure of course preparation was contingent on MAPS deficiency status.

For students with average levels of high school preparation, there was a significant difference in both final course grades and course success, with students earning higher grades and succeeding at high rates in MATH 1012 than in MATH 1011.

These results were also not affected by whether or not the measure of course preparation was contingent on MAPS deficiency status.

Research Question 8

For all students, to what extent is there a relationship between final course grade or course success and whether the student took MATH 1011 or MATH 1012?

Analysis

The sample contained 44 students who were enrolled in MATH 1011 and 75 students who were enrolled in MATH 1012. In each course, three students had W grades, and so were excluded from assessments based on the variable GRADE.

An independent Student's *t*-test for difference of means was conducted to determine whether there was a significant difference in final course grades between MATH 1011 and MATH 1012. An *F*-test for the significance of the difference between the variances of the two samples, CUCOURSE = 1 and CUCOURSE = 2, was performed. $F\left(40,71\right)=2.15$ and $p<0.01$, so the Student's *t*-test used an assumption of unequal variances. The sample showed no significant difference in final grades between those who were enrolled in MATH 1011 and those who were enrolled in MATH 1012, $t\left(61.6\right)=-1.77$, $p=0.09$.

The extent of relationship between course selection and final course grade was also examined by finding the point-biserial coefficient of association for the independent variables CUCOURSE and GRADE. The sample did not show a significant association of the variables, $r_{pb} = 0.18$, $t(111) = 1.94$, $p = 0.05$.

To determine whether there was a significant difference in the course success between the students who were enrolled in MATH 1011 and those who were enrolled in MATH 1012, Pearson's χ^2 test was applied. The difference in rates of success, 68% for MATH 1011 and 88% for MATH 1012, was found to be significant, $\chi^2(1,119) = 6.99$, $p = 0.01$.

Conclusions

For first year students overall, there was no significant difference in final grades between MATH 1011 and MATH 1012. However, there was a significant difference in course success; students were successful in MATH 1012 at a higher rate than in MATH 1011.

Research Question 9

To what extent is there a relationship between whether or not a student has MAPS deficiencies in mathematics and final course grades or course success for the combined population of students in MATH 1011 or MATH 1012?

Analysis

The sample contained 30 students with MAPS deficiencies. Ten of those students were enrolled in MATH 1011 and 20 were enrolled in MATH 1012. None of the students in the sample who had MAPS deficiencies withdrew from their course. The sample contained 89 students without MAPS deficiencies. Thirty-four of those students were enrolled in MATH 1011 and 55 were enrolled in MATH 1012. Six of the 89 students had W grades, and so were excluded from assessments based on the variable GRADE; those six students were evenly divided in enrollment in MATH 1011 and MATH 1012.

An independent Student's t-test for difference of means was conducted to determine whether there was a significant difference in final course grades for students with and without MAPS deficiencies. An F-test for the significance of the difference between the variances of the two samples, MAPS = 0 and MAPS =1, was performed. $F\left(29,82\right)=1.22$ and $p=0.24$, so the Student's t-test used an assumption of equal variances. The sample showed no significant difference in final course grades between the students with and without MAPS deficiencies in mathematics, $t\left(111\right)=-1.27$, $p=0.21$.

To determine whether there was a significant difference in course success between the students with and without MAPS deficiencies in mathematics, Fisher's exact test was applied. The sample showed no significant difference in course success, $p=0.52$.

Conclusions

There was no relationship between whether or not a student has MAPS deficiencies in mathematics and either final course grades or course success for the combined population of students in MATH 1011 or MATH 1012.

Research Question 10

To what extent is there a relationship between preparation level and final course grades or course success for the combined population of students in MATH 1011 or MATH 1012?

Analysis

Different levels of preparation, MAPS taken into consideration

To determine whether there was a significant difference in final course grades between groups with different levels of high school preparation, an independent samples one-way analysis of variance for difference of means was conducted. The sample showed no significant effect for high school preparation level on final grades, $F(2,110) = 1.69$, $p = 0.19$.

The extent of relationship between high school preparation level and final course grade was also examined by finding the Spearman's rank correlation coefficient for the independent variables LEVEL and GRADE. The data did not show a significant correlation of the variables, $r_s = 0.19$, $t(111) = 2.02$, $p = 0.05$.

To determine whether there was a significant difference in course success in between groups with different levels of high school preparation, Fisher's exact test was applied. The sample showed no significant dependence between course success and high school preparation level, $p = 0.71$.

The extent of relationship between high school preparation level and course success was also examined by finding the point-biserial coefficient of association for the independent variables LEVEL and SUCCESS. There was no significant association of the variables, $r_{pb} = 0.07$, $t(117) = 0.80$, $p = 0.43$.

Different strata of preparation, MAPS not taken into consideration

To determine whether there was a significant difference in final course grades between groups with different strata of high school preparation, an independent samples one-way analysis of variance for difference of means was conducted. The sample showed a significant effect for high school preparation strata on final grades, $F(2{,}110) = 4.13$, $p = 0.02$.

The extent of relationship between high school preparation strata and final course grade was also examined by finding the Spearman's rank correlation coefficient for the independent variables STRAT and GRADE. There sample showed a significant correlation of the variables, $r_s = 0.28$, $t(111) = 3.05$, $p < 0.01$.

To determine whether there was a significant difference in course success between groups with different strata of high school preparation, Fisher's exact test was applied. The sample showed no significant dependence between course success and high school preparation strata, $p = 0.13$.

The extent of relationship between high school preparation strata and course success was also examined by finding the point-biserial coefficient of association for the independent variables STRAT and SUCCESS. There was no significant association of the variables, $r_{pb} = 0.16$, $t(117) = 1.72$, $p = 0.09$.

Conclusions

When the measure for preparation level was contingent on MAPS status (the variable LEVEL), there was no relationship between preparation level and either final course grades or course success. When the measure for preparation level was not contingent on MAPS status (the variable STRAT), there was still no relationship between preparation levels and course success. There was, however, a positive relationship between these preparation levels (strata) and course grade.

Supplementary Analyses

To examine possible interactions between the course a student took and the student's high school mathematics preparation, six two-way independent samples analysis of variance tests were conducted. See Table 9 through Table 14 for ANOVA summary statistics. The tests consistently showed main effects for CUCOURSE on SUCCESS. The p-values for main effects of CUCOURSE on GRADE were consistently close to the 0.05 significance level. The tests showed no interactions for CUCOURSE with any of the preparation measures, whether outcomes were measured by SUCCESS or GRADE. The tests showed no main effects for MAPS or LEVEL on either SUCCESS or GRADE. However, the tests did show main effects for STRAT on both SUCCESS and GRADE.

Table 9

ANOVA Summary: MAPS Status and Course by Final Grade

Source	*SS*	*df*	*MS*	*F*	*p*
MAPS status	2.02	1	2.02	1.66	0.20
Course	4.58	1	4.58	3.75	0.06
MAPS × Course	0.24	1	0.24	0.20	0.66
Error	133	109	1.22		
Total	139.84	112			

Two-way analysis of variance examining possible interactions between MAPS status and course selected, as measured by final course grade. No significant interactions were found, $p = 0.66$. Results support the earlier conclusions the existence of a relationship between course selection and final grade, $p = 0.06$, and the lack of a relationship between MAPS status and final grade, $p = 0.20$.

Table 10

ANOVA Summary: MAPS Status and Course by Course Success

Source	*SS*	*df*	*MS*	*F*	*p*
MAPS status	0.06	1	0.06	0.40	0.53
Course	1.09	1	1.09	7.25	0.01
MAPS × Course	0.11	1	0.11	0.73	0.39
Error	17.29	115	0.15		
Total	18.55	118			

Two-way analysis of variance examining possible interactions between MAPS status and course selected, as measured by course success. No significant interactions were found, $p = 0.39$. Results support the earlier conclusions the existence of a relationship between course selection and course success $p = 0.01$, and the lack of a relationship between MAPS status and course success, $p = 0.53$.

Table 11

ANOVA Summary: Preparation Level and Course by Final Grade

Source	*SS*	*df*	*MS*	*F*	*p*
Level	4.17	2	2.09	1.74	0.18
Course	4.58	1	4.58	3.82	0.05
Level × Course	2.92	2	1.46	1.22	0.30
Error	128.17	107	1.20		
Total	139.84	112			

Two-way analysis of variance examining possible interactions between high school preparation levels, contingent on MAPS status, and course selected, as measured by final grade. No significant interactions were found, $p = 0.30$. Results support the earlier conclusions the existence of a relationship between course selection and final grade, $p = 0.05$, and the lack of a relationship between preparation level and final grade, $p = 0.18$.

Table 12

ANOVA Summary: Preparation Level and Course by Course Success

Source	*SS*	*df*	*MS*	*F*	*p*
Level	0.12	2	0.06	0.40	0.67
Course	1.09	1	1.09	7.24	0.01
Level × Course	0.33	2	0.17	1.10	0.34
Error	17.01	113	0.15		
Total	18.55	118			

Two-way analysis of variance examining possible interactions between high school preparation levels, contingent on MAPS status, and course selected, as measured by course success. No significant interactions were found, $p = 0.34$. Results support the earlier conclusions the existence of a relationship between course selection and course success, $p = 0.01$, and the lack of a relationship between preparation level and course success, $p = 0.67$.

Table 13

ANOVA Summary: Preparation Stratum and Course by Final Grade

Source	*SS*	*df*	*MS*	*F*	*p*
Stratum	9.77	2	4.89	4.34	0.02
Course	4.58	1	4.58	4.07	0.05
Stratum × Course	5	2	2.5	2.22	0.11
Error	120.49	107	1.13		
Total	139.84	112			

Two-way analysis of variance examining possible interactions between high school preparation strata, levels not contingent on MAPS status, and course selected, as measured by final grade. No significant interactions were found, $p = 0.11$. Results support the earlier conclusions the existence of a relationship between course selection and final grade, $p = 0.05$, and relationship between preparation stratum and final grade, $p = 0.02$.

Table 14

ANOVA Summary: Preparation Stratum and Course by Course Success

Source	*SS*	*df*	*MS*	*F*	*p*
Level	0.66	2	0.33	2.31	0.10
Course	1.09	1	1.09	7.65	0.01
Level × Course	0.69	2	0.35	2.42	0.09
Error	16.11	113	0.14		
Total	18.55	118			

Two-way analysis of variance examining possible interactions between high school preparation strata, levels not contingent on MAPS status, and course selected, as measured by course success. No significant interactions were found, $p = 0.09$. Results support the earlier conclusions the existence of a relationship between course selection and course success, $p = 0.01$, and the lack of a relationship between preparation stratum and course success, $p = 0.10$.

Chapter 5

Conclusions and Recommendations

Minimum Academic Preparation Standards

While a MAPS deficiency in mathematics is regarded as sign that a student is underprepared for college-level mathematics coursework, there appears to be little or no relation between whether a student is considered to be MAPS deficient and that student's performance in the course. Whether within a particular course or across all students in the sample, there was no significant relation between MAPS status and course performance. With no significant difference in course grades or course success found between students with and without MAPS deficiencies, the findings suggest that the MAPS standards may not be a useful measure for determining a student's readiness for introductory college-level mathematics coursework. It is recommended that the usefulness of MAPS status as a measure of student preparation be examined more closely in a larger scale study which includes all courses which fulfill the Quantitative Reasoning requirement for Arts & Sciences students and which do not have college-level prerequisites.

High School Preparation Levels

When categorizing level of high school preparation in a manner based on the assumption that students with MAPS deficiencies had below average levels of preparation (the variable LEVEL), there again appears to be little or no relation between level of high school preparation and student course performance. However, when the categorizations are made without regard to MAPS (the variable STRAT), course grade was found to be significantly affected by preparation level (stratum), although a similarly significant effect was not found for course success. These results would suggest that high school preparation is indeed relevant to college course success, but that high school background should be analyzed in ways independent of the MAPS standards. The results would also seem to indicate that preparation levels are more closely connected to measures of how strongly a student succeeds or fails in a course (the variable GRADE) than to the simple dichotomous issue of whether a student succeeds or fails (the variable SUCCESS). It is again recommended that a larger scale study, including more courses, be conducted. Factor analysis and generalized linear model techniques should be considered in any further analysis of high school preparation level to allow for the simultaneous consideration of different variable types.

Effect of Differing Courses

Students with MAPS deficiencies enrolled in MATH 1011 and MATH 1012 in proportions equivalent to the enrollment patterns for students without MAPS deficiencies. However, it is important to consider that first-year students have more than these two choices available to them for fulfilling the Quantitative Reasoning requirement. Course selection and enrollment issues should be examined in the larger context of all first year student options, including the option of not enrolling in a Quantitative Reasoning course in the first semester of college.

There was an apparent difference in student performance between MATH 1011 and MATH 1012, with higher mean grades and success rates for MATH 1012. It appears that the difference is concentrated in the students with average levels of high school preparation, with little or no effect on the performance of students with above or below average levels of preparation. It is recommended that first-year student performance in the two courses be examined in a larger scale study, which should include consideration of student intended major field of study as well as high school preparation measures. It is also recommended that similar comparative studies be made within any group of courses regularly offered by the Mathematics Department which have equivalent high school level prerequisites: MATH 1071 *Finite Mathematics for Social Science and Business*, MATH 1081 *Calculus for Social Science and Business*, MATH 1150 *Precalculus Mathematics*, and MATH 2510 *Introduction to Statistics*; MATH 1021 *Numerical and Analytical College Trigonometry*, MATH 1110 *The Spirit and Uses of Mathematics 1*, MATH 1410 *Mathematics for Secondary Educators*, and MATH 2380 *Mathematics for the Environment*; and MATH 1300 *Analytic Geometry and Calculus 1* and 1310 *Calculus, Stochastics, and Modeling.*

Future Considerations

Beginning in the summer of 2012, all incoming first-year students will be required to take an online mathematics placement test before being able to register for classes. Advisory, non-binding minimum scores on the placement test have been set for several courses from the Mathematics, Applied Mathematics, and Economics departments. There is no minimum score for enrollment in MATH 1011 or MATH 1012. Any future research should consider placement test score as a measure of student preparation. Future research will also need to examine whether the implementation of the placement test has an effect on which courses students with particular levels of high school mathematics preparation elect to take. It will be critical for analyses to be conducted of student placement test scores and course performance in relation to the initial advisory placement recommendations, particularly in the first few years of the placement program implementation.

Also beginning in the summer of 2012, the new student orientation programs for the College of Engineering and Applied Science and the College of Arts and Sciences will be undergoing significant restructuring, as will the entire program of academic advising for first-year students in the College of Arts & Sciences. These changes may also have an effect on which courses students with particular levels of high school mathematics preparation elect to take, which will be difficult to isolate from the potential effects of the new placement program. Overall, the interactions of student preparation levels and student course selections will need to be carefully monitored, along with any concomitant changes in overall student performance.

Appendices

Appendix A: Minimum Academic Placement Standards

The following is an excerpt from the University of Colorado, Boulder Catalog (University of Colorado, 2011a, pg. 7-8).

Policies Concerning MAPS Deficiencies

The policies of the Boulder campus with respect to completing MAPS course work after enrollment are as follows.

1. Appropriate missing MAPS course work is included in the hours for graduation.
2. All course work toward fulfillment of the MAPS must be taken for a letter grade.
3. It is strongly recommended that students enroll in and complete at least one MAPS course each term, beginning in the first term of enrollment, until such time as all MAPS are completed. This policy applies to new freshmen, transfer students, and students transferring from other academic units on the Boulder campus and from other campuses of the university. Some colleges or schools may impose a sanction if the student does not complete one course per semester toward meeting MAPS deficiencies.
4. All students who first enroll in one academic unit at CU-Boulder and subsequently transfer to another unit are required to meet the MAPS specified for the new unit, irrespective of their completion of MAPS units in their previous college or school.
5. Students in double-degree programs must meet MAPS requirements of both degree-granting units.
6. Students must consult with a CU-Boulder academic advisor (or read their college or school's academic publications) to determine which specific courses may be used to meet a MAPS requirement.
7. Students who complete 50 percent or more of their secondary schooling in a non-U.S. system are exempt from MAPS. Please also review the chart on page 7.

One unit equals one year of high school study or one semester of college course work.					
	College of Architecture and Planning	*College of Arts and Sciences / School of Journalism and Mass Communication*	*Leeds School of Business*	*College of Engineering and Applied Science*	*College of Music*
English	**4**	**4** (includes 2 of composition)	**4** (includes 2 of composition)	**4**	**4**
Mathematics	**4** (includes at least 2 of algebra, 1 of geometry, and 1 of preparatory math such as trigonometry, analytic geometry, or elementary functions)	**4** (includes at least 2 of algebra, 1 of geometry, and 1 of preparatory math such as trigonometry, analytic geometry, or elementary functions)	**4** (includes at least 2 of algebra, 1 of geometry, and 1 of preparatory math such as trigonometry, analytic geometry, or elementary functions)	**4** (includes at least 2 of algebra, 1 of geometry, and 1 of preparatory math such as trigonometry, analytic geometry, or elementary functions)	**4**
Natural science	**3** (includes physics and/or biology)	**3** (includes 2 of lab science, 1 of which must be either chemistry or physics)	**3** (includes 2 of lab science, 1 of which must be either chemistry or physics)	**3** (includes 1 year of physics AND 1 of chemistry or biology, OR 2 of chemistry and 1 of physics or biology, OR 2 of biology AND 1 of chemistry or physics)	**3**
Social science	**3**	**3** (includes 1 of U.S. or world history and 1 of geography; if U.S. history is used to meet the history requirement, the geography requirement may be met with 1/2 unit of geography and 1/2 unit of world history)	**3** (includes 1 of U.S. or world history and 1 of geography; if U.S. history is used to meet the history requirement, the geography requirement may be met with 1/2 unit of geography and 1/2 unit of world history)	**3**	**3**
Single foreign language	**2**	**3**	**3**	**3** (or 2 units in each of 2 separate foreign languages)	**2**
Academic elective	**1**				**2** (in the arts)
TOTAL UNITS	**17**	**17**	**17**	**17**	**18**

Appendix B: The Quantitative Reasoning Core Requirement

The following is an excerpt from the University of Colorado, Boulder Catalog (University of Colorado, 2011a, pg. 69-70).

Quantitative Reasoning and Mathematical Skills (QRMS) (3–6 semester hours).

Liberally educated people should be able to think at a certain level of abstraction and to manipulate symbols. This requirement has two principal objectives. The first is to provide students with the analytical tools used in core curriculum courses and in their major areas of study. The second is to help students acquire the reasoning skills necessary to assess adequately the data which will confront them in their daily lives. Students completing this requirement should be able to: construct a logical argument based on the rules of inference; analyze, present, and interpret numerical data; estimate orders of magnitude as well as obtain exact results when appropriate; and apply mathematical methods to solve problems in their university work and in their daily lives.

Students can fulfill the requirement by passing one of the courses or sequences of courses listed below or by passing the CU-Boulder QRMS proficiency exam. Students who take approved CU-Boulder course work to fulfill this requirement must take the course for a letter grade and receive a passing grade of *D*- or higher.

ECEN 1500-3. Sustainable Energy

ECON 1078-3 Mathematical Tools for Economists 1

*MATH 1012-3 Quantitative Reasoning and Mathematical Skills (same as QRMS 1010)

MATH 1110-3 and 1120-3 The Spirit and Uses of Mathematics 1 and 2

MATH 1130-3 Mathematics From the Visual Arts (same as QRMS 1130)

*MATH 1150-4 Precalculus Mathematics

*MATH 1410-3 Mathematics for Secondary Educators

*MATH 2380-3 Mathematics for the Environment (same as QRMS 2380)

PHYS 1010-3 Physics of Everyday Life 1

PHYS 1020-4 Physics of Everyday Life 2

PSCI 2075-3 Quantitative Research Methods

PSCI 3105-3 Designing Social Inquiry

Any 3-credit math module: MATH 1011-3, MATH 1071-3, or MATH 1081-3.

Any 3 credits of mathematics courses numbered *MATH 1300 and above or applied mathematics courses numbered *APPM 1350 and above.

Note: This course is approved for the Colorado statewide guaranteed transfer program. Further information about the statewide guaranteed transfer program can be found at the website of the Colorado Commission on Higher Education,* **highered.colorado.gov/Academics/Transfers/gtPathways/curriculum.html.

Appendix C: Selected Mathematics Course Descriptions

The following are excerpts from the University of Colorado, Boulder Catalog (University of Colorado, 2011a, pg. 69-70).

MATH 1011-3. Fundamentals and Techniques of College Algebra. Covers simplifying algebraic expressions, factoring linear and quadratic equations, inequalities, exponentials, logarithms, functions, and graphs, and systems of equations. Credit not granted for this course and MATH 1010, 1020, and 1150. Prereq., one year high school algebra or placement exam score for MATH 1000. Meets MAPS requirement for mathematics. Approved for arts and sciences core curriculum: quantitative reasoning and mathematical skills.

MATH 1012-3. Quantitative Reasoning and Mathematical Skills. Promotes mathematical literacy among liberal arts students. Teaches basic mathematics, logic, and problem-solving skills in the context of higher level mathematics, science, technology, and/or society. This is not a traditional math class, but is designed to stimulate interest in and appreciation of mathematics and quantitative reasoning as valuable tools for comprehending the world in which we live. Credit not granted for this course and QRMS 1010. Meets MAPS requirement for mathematics. Approved for arts and sciences core curriculum: quantitative reasoning and mathematical skills.

MATH 1021-2. Numerical and Analytical College Trigonometry. Covers trigonometric functions, identities, solutions of triangles, addition and multiple angle formulas, inverse and trigonometric functions, and laws of sines and cosines. Credit not granted for this course and MATH 1150, 1030 or 1040. Prereqs., MATH 1011 or 1020, or placement exam score for MATH 1030, or 1 1/2 years or high school algebra and 1 year of high school geometry.

MATH 1071-3. Finite Mathematics for Social Science and Business. Discusses systems of linear equations and introduces matrices, linear programming, and probability. Prereq., MATH 1011 or 1000, placement exam score for MATH 1020, or one and a half years of high school algebra. Credit not granted for this course and MATH 1050, 1060 and 1070. Approved for arts and sciences core curriculum: quantitative reasoning and mathematical skills.

MATH 1081-3. Calculus for Social Science and Business. Covers differential and integral calculus of algebraic, logarithmic, and exponential functions. Prereq., MATH 1011, 1071, 1010, or 1070 or placement exam score for MATH 1020 or two years high school algebra. Credit not granted for this course and MATH 1080, 1090, 1100, 1300, 1310, APPM 1350, and ECON 1088. Approved for arts and sciences core curriculum: quantitative reasoning and mathematical skills.

MATH 1110-3. The Spirit and Uses of Mathematics 1. For liberal arts students and prospective elementary teachers. Includes a study of problem-solving techniques in mathematics, the uses and role of mathematics in our society, and the structure of our familiar number systems. Additional topics are chosen from number theory, ancient numeration systems, computer science, modern geometry and algebra, and elementary logic. Prereq., one year of high school algebra and one year of plane geometry. The combination MATH 1110 and 1120 is approved for arts and sciences core curriculum: quantitative reasoning and mathematical skills.

MATH 1150-4. Precalculus Mathematics. Develops techniques and concepts prerequisite to calculus through the study of trigonometric, exponential, logarithmic, polynomial, and other functions. Prereq., one and a half years of high school algebra. Students having credit for college algebra and trigonometry may not receive additional credit for MATH 1150. Students with credit for college algebra receive only 2 additional hours of credit for MATH 1150. Similar to MATH 1000, 1010, 1020, 1011, 1021, 1030, and 1040. Meets MAPS requirement for mathematics. Approved for arts and sciences core curriculum: quantitative reasoning and mathematical skills.

MATH 1300-5. Analytic Geometry and Calculus 1. Topics include limits, derivatives of algebraic and trigonometric functions, applications of the derivative, integration and application of the definite integral. Prereqs., two years high school algebra, one year geometry, and 1/2 year trigonometry or MATH 1150. Credit not granted for this course and MATH 1081, 1310, APPM 1345, 1350, and

ECON 1088. Similar to MATH 1080, 1090, and 1100. Approved for arts and sciences core curriculum: quantitative reasoning and mathematical skills.

MATH 1310-5. Calculus, Stochastics, and Modeling. Calculus, probability, statistics, and discrete and continuous modeling are central to understanding the behavior of complex systems, ranging from gene networks and cells to brains and ecosystems. This course is similar to MATH 1300, but a greater emphasis is placed on relevance and applications to complex systems. Especially recommended for biology majors. Prereq., 2 years high school algebra, 1 year geometry, and 1/2 year trigonometry, or MATH 1150. Credit not granted for this course and MATH 1080, 1081, 1090, 1100, 1300, APPM 1350, or ECON 1088. Approved for arts and sciences core curriculum: quantitative reasoning and mathematical skills

MATH 1410-3. Mathematics for Secondary Educators. Assists students in meeting state mathematics certification requirements. Topics include problem solving, number systems, geometry and measurement, probability and statistics. Enrollment is restricted to students already admitted to or intending to apply for admission to the secondary teacher education program. Prereqs., one year high school algebra, one year geometry. Approved for arts and sciences core curriculum: quantitative reasoning and mathematical skills.

MATH 2380-3. Mathematics for the Environment. An interdisciplinary course where analysis of real phenomena such as acid rain, population growth, and road-killed rabbits in Nevada leads to consideration of various fundamental concepts in mathematics. One-third of the course consists of individual projects chosen by students. Prereq., proficiency in high school mathematics. Credit not granted for this course and QRMS 2380. Approved for arts and sciences core curriculum: quantitative reasoning and mathematical skills.

MATH 2510-3. Introduction to Statistics. Elementary statistical measures. Introduces statistical distributions, statistical inference, and hypothesis testing. Prereq., two years of high school algebra. Credit not granted for this course and MATH 4520/5520 or MATH 3510.

November 17, 2011

Carrie Muir
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4905 Osage Dr #224 Boulder, CO 80303

Larry Dlugosh
Department of Educational Administration
141C TEAC, UNL, 68588-0360

IRB Number: 20111112103EP
Project ID: 12103
Project Title: AN ANALYSIS OF FINAL COURSE GRADES IN TWO DIFFERENT ENTRY LEVEL MATHEMATICS COURSES BETWEEN AND AMONG FIRST YEAR COLLEGE STUDENTS WITH DIFFERENT LEVELS OF HIGH SCHOOL MATHEMATICS PREPARATION

Dear Carrie:

This letter is to officially notify you of the approval of your project by the Institutional Review Board (IRB) for the Protection of Human Subjects. It is the Board□s opinion that you have provided adequate safeguards for the rights and welfare of the participants in this study based on the information provided. Your proposal is in compliance with this institution□s Federal Wide Assurance 00002258 and the DHHS Regulations for the Protection of Human Subjects (45 CFR 46). Your project was approved as an Expedited protocol, category 5.

Date of EP Review: 10/18/2011

You are authorized to implement this study as of the Date of Final Approval: 11/17/2011. This approval is Valid Until: 11/16/2012.

We wish to remind you that the principal investigator is responsible for reporting to this Board any of the following events within 48 hours of the event:
* Any serious event (including on-site and off-site adverse events, injuries, side effects, deaths, or other problems) which in the opinion of the local investigator was unanticipated, involved risk to subjects or others, and was possibly related to the research procedures;
* Any serious accidental or unintentional change to the IRB-approved protocol that involves risk or has the potential to recur;
* Any publication in the literature, safety monitoring report, interim result or other finding that indicates an unexpected change to the risk/benefit ratio of the research;
* Any breach in confidentiality or compromise in data privacy related to the subject or others; or
* Any complaint of a subject that indicates an unanticipated risk or that cannot be resolved by the research staff.

For projects which continue beyond one year from the starting date, the IRB will request continuing review and update of the research project. Your study will be due for continuing review as indicated above. The investigator must also advise the Board when this study is finished or discontinued by completing the enclosed Protocol Final Report form and returning it to the Institutional Review Board.

If you have any questions, please contact the IRB office at 472-6965.

Sincerely,

Julia C. Torquati

Julia Torquati, Ph.D.
Chair for the IRB

UNIVERSITY OF Nebraska Lincoln

February 22, 2012

Carrie Muir
Department of Educational Administration
4905 Osage Dr #224 Boulder, CO 80303

Larry Dlugosh
Department of Educational Administration
141C TEAC, UNL, 68588-0360

IRB Number: 20111112103COLL
Project ID: 12103
Project Title: AN ANALYSIS OF FINAL COURSE GRADES IN TWO DIFFERENT ENTRY LEVEL MATHEMATICS COURSES BETWEEN AND AMONG FIRST YEAR COLLEGE STUDENTS WITH DIFFERENT LEVELS OF HIGH SCHOOL MATHEMATICS PREPARATION

Dear Carrie:

The Institutional Review Board for the Protection of Human Subjects has completed its review of the Request for Change in Protocol submitted to the IRB.

The change request has been approved to expand data collection to include first year students in the Fall 2011 semester, and for the investigator to collect the data on student grades in high school mathematics courses as well.

We wish to remind you that the principal investigator is responsible for reporting to this Board any of the following events within 48 hours of the event:
* Any serious event (including on-site and off-site adverse events, injuries, side effects, deaths, or other problems) which in the opinion of the local investigator was unanticipated, involved risk to subjects or others, and was possibly related to the research procedures;
* Any serious accidental or unintentional change to the IRB-approved protocol that involves risk or has the potential to recur;
* Any publication in the literature, safety monitoring report, interim result or other finding that indicates an unexpected change to the risk/benefit ratio of the research;
* Any breach in confidentiality or compromise in data privacy related to the subject or others; or
* Any complaint of a subject that indicates an unanticipated risk or that cannot be resolved by the research staff.

This letter constitutes official notification of the approval of the protocol change. You are therefore authorized to implement this change accordingly.

If you have any questions, please contact the IRB office at 472-6965.

Sincerely,

Julia C. Torquati

Julia Torquati, Ph.D.
Chair for the IRB

Association for the Accreditation of Human Research Protection Programs, Inc. Full Accreditation

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