STUDENT ACHIEVEMENT AND CLASSROOM CONNECTIVITY TECHNOLOGY IN A TWO-YEAR COLLEGE MATHEMATICS CLASSROOM

By

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This is dedicated to my son, Gavin Cifuentes, who inspires me to be a better mother and person each and every day, and to my late grandmother, Dora Lee Staub, who always believed in me.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AA	Associates of Arts degree
AACC	American Association of Community Colleges
AAS	Associates of Applied Science degree
ACT	American College Testing
AIMS	Arizona Instrument to Measure Standards
AMATYC	American Mathematics Association for Two-Year Colleges
AS	Associates of Science degree
BAS	Bachelor of Applied Science degree
BS	Bachelor of Science degree
CAS	Computer Algebra System
CCT	Classroom Connectivity Technology
CCMS	Classroom Connectivity in Mathematics and Science Project study by Dr. Douglas Owens
CRS	Classroom Response System
FCS	Florida College System
FLDOE	Florida Department of Education
FTIC	First Time in College
GPA	Grade Point Average
IRE	Initiate, Response, and Evaluate
MSLQ	Motivated Strategies for Learning Questionnaire
NCES	National Center for Education Statistics
NCTM	National Council of Teachers of Mathematics
NSCRC	National Student Clearinghouse Research Center
PERT	Postsecondary Education Readiness Tests

QEP	Quality Enhancement Plan
SACSCOC	Southern Association on Colleges and Schools Commission on Colleges
SAT	Scholastic Aptitude Test
SUS	State University System
TIPBS	Teacher Instructional Practice and Beliefs Survey
US	United States

Abstract of Dissertation Presented to the Graduate School
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STUDENT ACHIEVEMENT AND CLASSROOM CONNECTIVITY TECHNOLOGY IN A TWO-YEAR COLLEGE MATHEMATICS CLASSROOM

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Success in mathematics has been a critical problem in the United States education system for years. In the two-year college classroom, college level mathematics prove to be a gatekeeper for student success, and therefore, graduation. College Algebra is a particular gatekeeper for students at for two-year colleges. This study focused on an intervention to improve student success in College Algebra and its prerequisite course, Intermediate Algebra.

This study involved classroom connectivity technology, the TI-Navigator™ system with TI-Nspire™ calculators, as an instructional tool in Intermediate Algebra and College Algebra classrooms at a two-year college. Instructors participated in a two-year professional development series in discourse practices with the TI-Navigator™ system and the uses of the TI-Navigator™ system.

This study involved 520 student participants. Researchers collected the course grades and student scores from the departmental final exam, and analyzed the data to see if the use of the TI-Navigator™ system as an instructional tool increased these measures. The results were the same for both Intermediate Algebra and College Algebra. There was no statistical significant difference found in course grades between

the year one students not using the TI-Navigator^{TM} system and the year two students with the use of the TI-Navigator^{TM} system as a tool for the instruction. However, there was a statistically significant difference in the departmental final exam scores showing an increase in scores from year one to year two students. The mean effect size was d = .32 for Intermediate Algebra was d = .42 for College Algebra from year one to year two.

CHAPTER 1
INTRODUCTION

Introduction of the Problem

National leaders, state government officials and educational agencies have expressed concern for the status of mathematics education in the United States (US) for years. President Barack Obama launched the "Educate to Innovate" campaign in 2009 to move the nation's students from middle to top status in mathematics and science (The White House, 2009). Being successful in high-level mathematics – such as trigonometry, and precalculus - has been shown to be the one best indicator in predicting success for college (Adelman & US, 1999, 2006) and mathematics is known to be a gatekeeper for student graduation from college (Mesa, Wladis, & Watkins, 2014). This study focused on a teaching methodology at the secondary level that may improve students' success in college-level mathematics and acquisition of mathematics skills.

Background of the Problem

Of the estimated 2,868,000 students graduating from high school in 2014, approximately 706,000 enrolled in a two-year college (US Department of Labor, Bureau of Labor Statistics, 2015). That is an estimated 25% of students exiting high school who enrolled in a two-year college. In Florida, an even higher percentage of high school graduates chose to enroll in a two-year college; approximately 65% of Florida students exiting high school enrolled in a two-year college whereas 31% enrolled in a state university system (SUS) institution (Florida College System (FCS), 2013). Most two-year colleges are open-access institutions accepting any student regardless of age who has received a high school diploma or GED, and recent high school graduates typically represent only a portion of students entering a two-year college. Many students return to two-year colleges after a long academic break due to a variety of factors. For instance, entering students may be older individuals who are changing career paths or learning a new professional trade. The two-year college focuses on Associate of Arts (AA) degrees for entry into undergraduate studies toward a bachelor's degree, and Associates of Science (AS) degree, Associates of Applied Science (AAS) degree, and certificate programs aimed toward local business and technical employment needs.

Two-year colleges have five missions: a) preparing students for transfer to a four-year institution, b) vocational certification, c) general education coursework necessary for an associate's degree, d) community education, and e) retraining employees for a changing economy (Mesa et al., 2014). However, the landscape of two-year colleges is changing in order to meet the changing needs and interests of students. For example, in 2008, the state of Florida enacted Senate Bill 1716 allowing two-year colleges in the FCS to begin offering four-year degrees similar to four-year universities in the SUS (Florida Senate, 2014). However, these four-year degree offerings are limited to Bachelor of Science (BS) and Bachelor of Applied Science (BAS) degrees that meet local workforce demand and projected growth need. To date, 24 out of the 28 colleges in the FCS offer BS and/or BAS degrees; however, FCS has remained open-access to the student population for their AA, AS, AAS, and continuing education programs.

As open-access institutions, two-year colleges continually face students who want an education but who need remedial coursework. According to the National Center for Education Statistics (NCES), an estimated 39% of 12th grade students score at or above cut scores needed on proficiency tests for these students to be considered academically prepared for college-level mathematics coursework, and only 26% of 12th grade students were considered proficient in 2013 (NCES, 2014a). The state of Florida fared worse, with only 19% of 12th grade students scoring at a proficient level, while the remaining 81% possibly needed remediation (NCES, 2014a). The American Association of Community Colleges (AACC) stated that of the 68% of two-year college students taking at least one remedial course, many drop out before being able to take college-level coursework (AACC, 2014). The number of students taking remedial mathematics courses at two-year colleges in 2010 was 1,150,000, while their counterparts at four-year universities were 334,000 (Blair, Kirkman, & Maxwell, 2013). This figure shows the staggering number of ill-prepared students entering two-year colleges. At one two-year college in North Central Florida, 63.5% of entering students required some form of remediation, with 62.6% requiring remediation specifically in mathematics in the 2013-2014 academic year (Florida Gateway College, 2015).

Furthermore, in 2014, the state of Florida enacted Senate Bill 1720. This statute opened the door for students who were in the military or who had entered 9th grade by the 2003-2004 school year and graduated from the Florida school system to bypass both placement testing and remedial education. Hence, potentially ill-prepared students--some having been away from any educational studies for seven years, or more for military members--could immediately take college-level mathematics classes without being tested for their proficiency level. Furthermore, this bill will eventually eliminate remedial education curricula since the bill provided a date of cutoff for students who must test into college-level coursework. The number of Florida students taking remedial mathematics has dramatically changed since this enactment. At the same small college in North Central Florida, the number of students required to take remedial mathematics dropped to 34% in the 2014-2015 academic year (FGC, 2015). Unfortunately, this bill has increased the number of students taking college-level mathematics who are not college ready.

Two-year college students are often quite different from either high school or four-year university students. As compared to the K-12 and four-year university populations, students taking classes at a two-year college are usually enrolled part-time, have full-time jobs, have dependents living at home, and are financially independent (Mesa, 2012; Mesa et al., 2014). Unlike a classroom at a four-year university, which is typically highly selective in admissions, a two-year college classroom will more likely have a larger array of age groups and some students studying for a particular occupational trade. Since college-readiness is not a requirement for admission into a two-year college, these students may require extensive remediation to get them prepared for college-level work.

The two-year college student is typically older, lower in socio-economic status, and lacking mathematics courses beyond high school. Two-year college students may need as many as three remedial mathematics courses, as determined by a college standardized placement exam like the SAT, ACT, or Postsecondary Education Readiness Test (PERT), before being eligible to take the first of the required two general education mathematics courses for college credit. Many do not persist. Two-year colleges across the nation are plagued with poor student retention and success rates due to low achievement of these underprepared students, while poor-performing students who turn to these colleges hoping for an improved future suffer frustration and setbacks. Underprepared students have lower course completion rates and greater attrition than college-ready students (Bailey, Jeong, & Cho, 2010; Grimes, 1997).

Two-year colleges have mathematics instructors who lack formal pedagogical training and teach from a behaviorist perspective (Hassad, 2011). In order to teach at a two-year college, mathematics instructors typically need a master's degree or higher in their subject matter but are not required to have completed any coursework in education or have a formal teaching certification. While all instructors have the knowledge-base of their subject matter, few have both knowledge-base of the subject matter and pedagogical training. If instructors are not aware of the best methods or practices in teaching mathematics, students may suffer from their instructors' lack of formal pedagogical training.

This study addressed pedagogical deficiencies two-year college mathematics instructors tend to have by providing intensive professional development to these instructors. This research examined the efficacy of an instructional strategy, used in some secondary education classrooms, for increasing student mathematics success in the two-year college classroom: classroom connectivity technology (CCT). Some studies provide strong rationale for utilizing communication as a model for the key to student success in mathematics and some stress the importance of CCT in the classroom. Several studies are addressed in the following chapter to show that coupling discourse with CCT increases student engagement and achievement. Instructors involved with this study were introduced to the pedagogical basics of discourse-based instruction and this was followed up with the main professional development for CCT to use as the instructional basis for the study. This study examined whether the introduction of CCT resulted in improved course grades and student scores on departmental final exams. It was hypothesized that students would have increased achievement for those classes in which the CCT was employed.

Statement of the Problem

With the focus of improving two-year college mathematics instruction to enhance student learning and success, this study was a natural extension from previous studies. Studies have demonstrated the efficacy of classroom connectivity to improve learning in mathematics for high school students (Irving et al., 2010; Pape et al., 2010). While the TI-Navigator™ system may increase student engagement in a college classroom (Powers & Champion, 2008), no studies have been found that focus specifically on student achievement at the two-year college. This study has bridged the gap by looking at how student achievement correlates with the use of TI-Navigator™ system in the two-year college mathematics classroom.

Purpose of the Study

The purpose of this study was to correlate classroom connectivity-based mathematics instruction to students' achievement in a two-year college mathematics classroom. Student achievement for this study is considered whether a student successfully completes the course with a C or higher and will be measured using final grades and departmental final exam scores. The researcher analyzed the impact of CCT on two-year college student achievement in mathematics and considered the effects over a two-year period beginning with professional development for the instructors in fall of 2009 and extending through spring of 2011.

Baseline data were collected in year one, and CCT data were considered in year two since the incorporation of CCT in the classroom took place at the beginning of year two. Student participants provided demographic information via surveys. There were a total of 520 students who participated in the multi-year study involving two different mathematics courses. Participants self-enrolled in Intermediate Algebra (MAT 1033) or College Algebra (MAC 1105) or both over the two-year period. MAT 1033 is a course that offers college elective credit toward a degree, but MAT 1033 does not satisfy general education mathematics requirements. Due to Senate Bill 1720, any student who graduated since 2007 may enter MAT 1033 without remediation. Students entering MAT 1033 are expected to be able to (1) solve equations involving square roots, numerical fractions, and decimals, (2) factor trinomials in order to solve a quadratic equation with factoring, (3) graph a line, and identify its slope, x-intercept, and y-intercept, (4) use the product rule for exponents, power rules for products and quotients, and (5) simplify expressions involving exponents. MAT 1033 topics include the simplification of radical, rational, and polynomial expressions and solving equations involving those expressions. It also covers the definition of function and solving quadratic equations by factoring, by the square root method, and by the quadratic formula, as well as solving two-variable systems of equations.

College Algebra is the next course in the algebra sequence and is considered a college level course that counts toward the six credits of general education mathematics requirement for completion of an AA degree. This course builds on the expressions covered in MAT 1033 but includes exponential and logarithmic functions, focusing intensely on their graphs. College Algebra also includes exponential and logarithmic equations and applications for their functions, as well as solving three-variable systems of equations.

Research Questions

Four primary research questions of this study were as follows:

1. Is there a significant difference in student scores on the Intermediate Algebra departmental final exam from year one to year two when the CCT was used as an instructional strategy?
2. Is there a significant difference in student grades in Intermediate Algebra from year one to year two when the CCT was used as an instructional strategy?
3. Is there a significant difference in student scores on the College Algebra departmental final exam from year one to year two when the CCT was used as an instructional strategy?
4. Is there a significant difference in student grades in College Algebra from year one to year two when the CCT was used as an instructional strategy?

Research Design

Every educational institution seeking accreditation through the Southern Association of Colleges and Schools Commissions on Colleges (SACSCOC) must develop a Quality Enhancement Plan (QEP), one of the core requirements for acquiring or maintaining SACSCOC accreditation. In 2007, a two-year college (the setting for this study) embarked in the development of its QEP to focus on student success in a four-course sequence in mathematics – Arithmetic, Elementary Algebra, Intermediate Algebra, and College Algebra. After a careful review of institutional data and the research of educational strategies, a college administrator, mathematics instructors, and a university researcher planned an intervention to change the way mathematics instructors taught in the two-year college. One of the mathematics instructors is the author of this dissertation and played a significant role in planning the professional development and data collection, but played a lesser role as the instructor to the student participants. The author instructed 10 student participants in spring 2010 and two student participants in fall 2010. The research team consisting of the author and the university researcher, developed the intervention through the identification and design of the goals and learning outcomes, and the development of the instructional strategies to meet these goals. Nine mathematics instructors, including the author, participated in a 17-day professional development series led by the university researcher that started in the fall of 2009 and ended in spring of 2011. The research team collected data on student grades and departmental final exam scores during the 2009-2011 school years.

Professional development in discourse theory and the TI-Navigator™ system for classroom connectivity, from Texas Instruments, was provided to the treatment group instructors. Final grades as well as departmental final exam scores were compared between the year one group and the year two group. Expectations were to observe a statistically significant increase in final grades and departmental final exam scores among students of year two.

Organization of the Remainder of the Study

This dissertation contains five chapters, including this introduction to the study to provide context and a brief overview. In the next chapter, a review of literature will establish how the social theory of constructivism informs the role of classroom discourse on the development of mathematical understanding, and the chapter will explore the role of classroom communication systems as tools for supporting classroom communication and mathematical understanding. Gaps in the literature will be addressed as a justification for the proposed research. Chapter three details the methodology of data collection, the intervention, and presents a plan of analysis. Chapter four provides the analysis of the quantitative data. Chapter five concludes with an examination of the implications of this research and outlines questions that the results of this project raise that might be addressed by future research.

Definition of Terms

- CLASSROOM CONNECTIVITY TECHNOLOGY (CCT). Technology within a classroom setting that wirelessly connects students together as a whole class with the instructor.
- TI-NAVIGATOR™ SYSTEM. A wireless access point and software connecting the student calculators to the instructor computer.
- TI-NSPIRE™ CAS. Computer algebra system (CAS) graphing calculators.

CHAPTER 2
REVIEW OF THE LITERATURE

The Two-Year College Student

Two-year colleges meet the needs of approximately 41% of the student undergraduate population in the US (AACC, 2015). In 2015, the National Student Clearinghouse Research Center (NSCRC) reported that 46% of students completing their four-year degree nationwide in the 2013-2014 academic year started their educational coursework at a two-year college. There is a greater percentage of students starting their postsecondary coursework at a two-year college in the state of Florida - 58% (NSCRC, 2015). This population has increased modestly since 2011 when 45% of graduates nationwide and 55% of graduates in Florida started at a two-year college (NSCRC, 2012). Many students choose the two-year college to complete their general education coursework at a reduced cost compared to the cost of the four-year university or to meet the needs of a vocational trade. In the 2013–2014 academic year, the average total cost of in-state, full-time attendance while living on campus at a two-year public college was $13,580, but $22,190 at a four-year university (NCES, 2015). For the two years of attendance at the two-year college, students could save over $17,000. The savings are a little less if students are living off campus. For instance, students' average cost when living with their parents varies from $8,530 for a two-year public college to $13,690 for their four-year counterpart. This would still show a little over a $10,000 savings for students choosing to take their first two years of college at a two-year college, and many students are choosing to do so.

From 2000 to 2010, undergraduate enrollment increased 27% at public two-year colleges (NCES, 2014b). Student enrollment in fall 2013 for two-year colleges was 7.0

million out of the 17.5 million total enrolled undergraduates (NCES, 2015). These colleges offer students an open-door policy that admits anyone who has a high school diploma or GED, and disregards factors such as low high school grade point average (GPA) or low placement exam scores that could limit entrance to a four-year university.

A two-year college classroom in the US typically has a larger older population taking undergraduate classes than does its four-year counterpart. In fall 2013, 16% of full-time undergraduate students at a two-year public college were between 25 and 34 years of age or older, and 11% were 35 or older as opposed to 9% and 3%, respectively, at a four-year public university (NCES, 2015). The percentages are more even for part-time students, with 24% of those enrolled at a two-year college on a part-time basis between 25–34 years old and 28% at four-year colleges.

According to the AACC 2015 Fact Book, most students enrolled in a two-year college work while taking classes. The Fact Book reports that 63% percent of students at a two-year college are employed full time. In fact, 22% of students are both a full-time student as well as employed full time. Forty percent of students are full-time students employed part time. An additional 32% are part-time students employed part time and 41% are part-time students employed full time (AACC, 2015).

The distribution of the student population is different at a two-year college than its four-year university. The two-year public college has a larger percentage of minority students than the four-year public university. A little over half of the population (54%) in a two-year college is Caucasian, while 15% are African American, 22% are Hispanic, 6% Asian, 1% American Indian, and 3% identified themselves as multiracial. Four-year public universities have a more predominantly white student population with 62%

Caucasian, 12% African American, 15% Hispanic, 7% Asian, 1% American Indian, and 3% multiracial students (NCES, 2015).

Students receiving financial aid of any kind are at 58% of the two-year college student population (AACC, 2015). Thirty-eight percent receive federal grants, and 19% receive federal loans. State aid is given to 12% of two-year college students, and the institutional aid is given to 13% of students (AACC, 2015).

The state of Florida has 28 two-year colleges that until a few years ago, offered exclusively two-year degrees (AA, AS and AAS) or vocational certifications. With the passage of Senate Bill 1716 in July 2008, Florida moved to allow most of these community colleges to offer baccalaureate degrees similar to four-year universities in the SUS (Florida Senate, 2014). This was designed to offer students a more cost-effective alternative (Floyd, Garcia Falconetti, & Hrabak, 2009). Even with this addition of the baccalaureate degree within the FCS, the main focus of the mission within the FCS has not changed: the FCS maintains its primary mission to respond to “community needs for postsecondary academic education and career degree education” (Florida Senate, 2014). Colleges within the FCS have remained open-access, focusing on lower level undergraduate instruction and are, in fact, forbidden from closing all of their associate degree programs (FCS, 2013). However, access to these baccalaureate degree programs is limited to an application process for the upper-division courses. Offering these degrees at FCS level has actually been shown to have a positive impact on student enrollments at the SUS level (Neuhard, 2013).

Furthermore, on May 20, 2013, Florida’s governor approved Senate Bill 1720. Section (s.) 1008.30(4) (a), Florida Statutes, exempts students who entered 9th grade in a Florida public school 2003-2004 and thereafter then graduated with a Florida standard high school diploma, as well as active duty military personnel from mandatory common placement testing and developmental education. This statute has now opened the door for students who were in the military or who have graduated from the Florida school system as far back as 2007 to bypass remedial education. Some colleges began a slow implementation in spring 2014, but full implementation was not required until fall 2014. Preliminary results from participating colleges of the spring 2014 implementation for first-time in college (FTIC) students, students showed a success rate of 55.3% for those exempt from testing into but taking MAT 1033, Intermediate Algebra, compared to 66.7% for those students who did take the college placement test for proper placement into their first college level mathematics course, Intermediate Algebra (Alexander, 2014).

Because college-readiness is not a requirement for admission into a two-year college, many two-year college students may require extensive remediation to get them prepared for college-level work. To be college-ready, a student would have the knowledge base to be able to enter into an entry-level, credit-bearing course through testing placement or evidence of previous prerequisite coursework. Even if students came college-ready they are not guaranteed success in their mathematics courses or to their college educational goals. One of the requisite general education mathematics courses, College Algebra, is considered a gatekeeper course in Florida's college system. A large percentage of students are unsuccessful in their first attempt at this course and remain unsuccessful after repeated attempts, therefore cutting off their chance of attaining a degree. In Florida, the average withdrawal rate for College

Algebra is 20%, and only 57% of students re-enroll in the class within the next two years (Florida Department of Education (FLDOE), 2007). These rates are consistent with most rates in college preparatory mathematics courses. The presumption is that students are entering college-level mathematics courses without the skills they need to succeed.

Mathematics Standards at the Two-Year College

In 1995 and 2006, the American Mathematical Association for Two-Year Colleges (AMATYC) published Crossroads in Mathematics and Beyond Crossroads, respectively, to set its standards for teaching mathematics at the two-year college level. AMATYC is the only national professional organization that focuses on the improvement of mathematics instruction in the first two years of college. The AMATYC's three categories of standards, intellectual development, content, and pedagogy, (Cohen, 1995) are similar to the National Council of Teachers of Mathematics' (NCTM) principles and standards (NCTM, 2000). Given the study was originally based on methods used in a secondary setting, it is important to compare the principles and standards from NCTM to those of AMATYC. AMATYC's intellectual development standards focus on the preferred methods of student learning. The content standard provides guidelines for content to be covered through the introductory college level mathematics sequence. The recommended use of instructional strategies for student construction of mathematical knowledge is listed in the pedagogy standard. The fourth standard, implementation, is a guide for instructors and departments on ways to support research on key issues, and it lists expectations of students, provides recommendations for implementation, and suggests actions for instructors and departments to support each recommendation.

AMATYC believes in the equitable distribution of educational teaching excellence and high expectations for students and that technology is an integral part to teaching and learning mathematics. Assessment is also considered an essential tool for both teacher and student to support and improve teaching and learning mathematics. AMATYC has broken curriculum into three separate principles—broadening, quantitative literacy, and relevance—to ensure the curriculum is broad enough for student choice and relevant for students' careers, as well as infusing quantitative literacy throughout the curriculum.

The learning principle for NCTM is "students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge" (NCTM, 2000, p. 20). AMATYC's innovation and inquiry principles encompass NCTM's principle for learning. Under the innovation principle, lessons should be thoughtfully crafted that engage and inspire students to learn through inquiry, problem solving, modeling, and collaboration (Wood, Bragg, Mahler, & Blair, 2006). Investigating mathematics through inquiry is the principle for which students build deeper understanding of mathematics. AMATYC thoroughly believes that students must be engaged in learning and, in particular, must actively build their knowledge in order to learn mathematics.

Within the AMATYC content standard the need for students to have knowledge of continuous and discrete modeling and deductive proofs is stated. The continuous and discrete modeling standard is intended to integrate modeling into the introductory college mathematics curriculum in order to improve student problem solving skills for future college mathematics courses as well as future career paths. Deductive proofs support conceptual understanding of mathematics through the formulation of arguments to prove or disprove mathematical concepts.

AMATYC addresses the need for students' ability to problem solve, reason and communicate their mathematics thinking, make mathematical connections, and to use representations for mathematical ideas, but AMATYC's problem solving standard is meant to make mathematics more meaningful and relevant to students. AMATYC recommends the use of problem solving strategies that require determination and perseverance, as well as for students to recognize inappropriate assumptions and to take risks beyond that of simple procedural approaches. There is an explicit modeling standard that expects students to use modeling to make predictions and informed decisions from real world contexts.

The five standards for pedagogy are guidelines for instructors to engage students in active learning. Since instructors at two-year colleges often lack the formal training on how to teach the content, these standards help to address methodologies mathematics instructors should incorporate into their teaching repertoire. AMATYC acknowledges that "knowledge cannot be 'given' to students," clearly going against mainstream lecture-style teaching and supporting the belief that students must construct their own knowledge (Wood et al., 2006, p. 6). The pedagogy standards are analogous to the Intellectual Development standards that address student involvement in learning. Those standards are teaching with technology, active and interactive learning, making connections, using multiple strategies, and experiencing mathematics. The teaching with technology standard expects instructors to use technology appropriately for instructional purposes. AMATYC also wants instructors to cultivate active learners by promoting writing, reading, speaking, and collaborative activities so students can learn to work with others and communicate mathematically. Instructors should involve students in meaningful activities so students can build connections within mathematics as well as with other disciplines. AMATYC expects instructors to use multiple strategies, including teaching through questioning, and for instructors to provide a learning experience through projects and apprenticeships to promote independent thinking.

The fourth set of standards in Beyond Crossroads (Wood et al., 2006) addresses implementation and are meant to be guidelines for instructors, departments and colleges for improving mathematics education for the first two years of college. These five standards address mathematics education at any two-year college holistically. Mathematics instructors and departments will:

1. create an environment that optimizes the learning of mathematics for all students,
2. use results from ongoing assessment of student learning of mathematics to improve curricula, materials, and teaching methods,
3. develop, implement, evaluate, assess, and revise courses, course sequences, and programs to help students attain a higher level of quantitative literacy and achieve their academic and career goals,
4. use a variety of instructional strategies that reflect the results of research to enhance student learning, and
5. hire qualified mathematics faculty, and these faculty will engage in ongoing professional development and service (Wood et al., 2006, pp. 13–14).

These principles and standards set forth by an organization specifically for teaching mathematics at a two-year college guided the design of the experiment analyzed in this research study. The following section details the theoretical framework for discourse in the classroom followed by the use of technology. Finally, this chapter consider the importance of integrating both as a classroom practice.

Student Engagement through Discourse

Social learning theorists believe learning occurs through social interactions (Brown, Collins, & Duguid, 1989; Bruner, 1986; Dewey, 1916; Lave & Wenger, 1991; Vygotsky, 1978) and that we can understand concepts in the context of communication with others (Vygotsky, 1978). For cognitive development, individuals must be actively constructing knowledge and cannot sit passively in a learning experience. Students are "more likely to internalize, understand, and remember material learned through active engagement in the learning process" in social situations (Bonwell & Sutherland, 1996). Discourse is integral in the construction of knowledge. Social theorists view the mind as social and conversational, conceptualizing the individual and the social realm as interconnected (Ernest, 2010). An individual begins constructing knowledge through a conversation in one's thoughts and conveys those thoughts through social interactions symbolically or verbally. These thoughts or beliefs are reflected through discourse until they are molded into knowledge. Social constructivists believe that "discourse is the primary symbolic, mediational tool for cognitive development" (Palincsar, 1998, p. 361). But as Sfard (2001) put it, "there is more to discourse than meets the ear" (p. 13). Cobb, Boufi, McClain, & Whitenack (1997) looked at the contributions of reflective discourse and collective reflection in the mathematical development of students. Reflective discourse is a sociological construct suggesting relationships between classroom discourse and mathematical development (Cobb et al., 1997). They characterized reflective discourse by the "repeated shifts such that what the students and teacher do in action subsequently become an explicit object of discussion" and collective reflection as the "communal activity of making what was previously done in action an object of reflection" (p. 258). The teacher's role is to guide and initiate shifts in the discourse so students can reorganize their thinking, but ultimately the students are actually constructing the knowledge (Cobb et al., 1997). Wood (1999) stated that this process of "contradiction and resolution is central to the transformation of thought" and evidence showed "that classroom discussion is important in students' development of mathematical concepts" (p. 171). Classrooms active in discourse between teachers and students with higher order thinking and explanation create an environment that has been shown to increase levels of student learning (Brophy, 1988; Pratton & Hales, 1986). While the efficacy of such discourse-rich classrooms has been shown in secondary schools, this active environment is less likely to show up in a college mathematics classroom; in fact, the college mathematics classroom is the only place on campus in which the student is not expected to have any opinion at all (Stage, 2001).

Some college instructors seem to prefer a passive, lecture-based teaching method, rather than a method requiring students and teacher to engage in high levels of discourse (Burns & Myhill, 2004; Daines, 1985; Kawanaka & Stigler, 1999; Stage, 2001). Students in higher education are most likely not going to be given the opportunity to clarify their conceptual understanding orally (Fisher & Grant, 1983), and when prompted with questions, they tend to be lower-order in nature requiring only procedural recall (Kawanaka & Stigler, 1999). A discourse pattern study by Tsay, Judd, Hauk, and Davis (2011) took place in two college algebra classrooms at a four-year university in the US. Their primary interest was to look at discourse patterns between student and instructor over the course of a semester in college algebra. The university setting had a full-time student enrollment of over 50,000 and more than 100 mathematics faculty. The study contained 70 students in two college algebra classes taught by one instructor. They found that the instructor's discourse pattern was lecture in nature approximately 65% of the time. This instructor presented lectures in chunks covering a concept or problem-solving method. There was a sense-making portion of the class which took place approximately 25% of the time. The instructor would "initiate the responsibility of the sense-making as a shared effort" (p. 221). The sense-making pattern was characterized by these four components:

1. Instructor encouraged students' participation and discussion.
2. Students responded to him.
3. Instructor verbally rephrased or reorganized students' representation/connections.
4. Instructor encouraged students to reason or debate about the representation and/or connections with each other (p. 220).

This interaction allowed students to make sense of the concept, but was not the predominant activity of the class.

Development of conceptual knowledge requires an environment in which students are afforded the opportunity to engage in higher order cognitive thinking (Krathwohl, 2002). This environment needs to be open, free of fear, and free of student ridicule. In order to create an open environment, communicating about mathematics needs to be a central focus in the classroom (Walshaw & Anthony, 2008). These classrooms should have three types of question directionality: teacher-to-student, student-to-student, and student-to-teacher. Student-to-teacher questions are those that students ask to teachers for possible clarification of content. Student-to-student questions are the interactions between students for clarification or justification of content matter. The types of questions teachers use for teacher-to-student interactions are recitation or authentic. Recitation are considered questions that elicit known answers and require very little mathematical reasoning or explanation of the answer. These questions would fall into the Initiate-Response-Evaluate (IRE) pattern of discourse that is common in most classrooms (Cazden, 2001). IRE patterns are started by the teacher initiating a question that the student answers, and then the teacher evaluates the validity of the student's answer. Authentic questions, however, promote responses that require reasoning, explanation, and/or justification. Each question has a level of cognitive load either lower or higher order level. The lower order cognitive load questions produce recall or restating of known facts, whereas, higher order cognitive load questions encourages the student to manipulate the information in ways to transform the meaning and implication. Higher order cognitive load questions elicit an analysis, generalization, synthesis, and/or explanation of a final conclusion or interpretation from the student (Nystrand, Wu, Gamora, Zeiser, & Long, 2003). Based upon the answers that are provided by these questions, uptake of correct and incorrect answers allows for scaffolding, which is social support for student achievement. Uptake of correct and incorrect answers refers to ways in which the teacher "takes up" (i.e., explores, engages with, discusses, analyzes, provides rationale to support) correct and incorrect responses as objects of classroom discourse (Pape et al., 2008). Uptake occurs when a teacher asks a student about something another student stated (Nystrand et al., 2003). Here, teachers can press for student involvement, elaboration, explanation, and/or justification. Teachers press students to elaborate their ideas or to make their responses explicit, and then follow students' answers with a request for deeper thinking (Pape et al., 2008). This interaction would lead to sense-making.

Teachers should establish social norms as well as sociomathematical norms at the onset of the class. Yackel and Cobb (1996) describe sociomathematical norms as norms that specifically support mathematical thinking. Students do not only question, explain, and work together to solve problems, but they question each other through pressing for mathematical reasoning, explain using mathematical argumentation, and then reach a class consensus through mathematical reasoning and proof (Yackel & Cobb, 1996). Talking about talking about mathematics defines teacher expectations and the acceptable responses, arguments, and justifications from students in the mathematics classroom. Teachers need to help students learn how to talk about mathematics (Cobb, Wood, & Yackel, 1993). Students should have a clear understanding of these expectations and should also be able to express their own mathematical thinking freely. Moreover, they should be able to explain, argue, and defend their own mathematical ideas as well as the ideas of others (Cohen, 1995; NCTM, 2000; Walshaw & Anthony, 2008; Wood, et al., 2006). Through this discussion and argumentation of mathematics, students can justify and co-construct--or taken-as-shared--mathematical meanings and practices (Cobb, Wood, Yackel, & McNeal, 1992). Setting sociomathematical norms will establish an acceptable clear explanation and an efficient solution for any mathematical problem (Bowers, Cobb, & McClain, 1999; Yackel & Cobb, 1996). With sociomathematical norms established, the instructor should seek to ask a balance of higher order and lower order questions and query students utilizing both visual and oral representations of the concepts (Cohen, 1995; NCTM, 2000; Wood et al., 2006).

The Pape et al. (2010) study was part of the Classroom Connectivity for Mathematics and Science Achievement (CCMS) project. CCMS was a large-scale project spanning a four-year period throughout the US and parts of Canada. A more in-depth look into this project and the CCT used in this project will follow in the next section. The focus of the Pape et al. (2010) study was on discourse patterns over the first year of the project. The study's focus was to describe typical patterns of interaction within a sample of US Algebra I classrooms, and to explore the relationship between patterns of interactions and student achievement (p. 3). There were 33 teachers in this study from nine states with 58% from suburban schools, 33% from urban schools, and 9% from rural schools. These teachers were mainly Caucasian (88%) and female (79%). Classroom observations and videotaping were held over two consecutive days and their classroom transcriptions were analyzed for this study. This study found primarily teacher-led discourse patterns and non-instructional statements dominated the classroom, with an average of 101.24 questions asked over a 60-minute period with teachers asking on average 90.58 of these questions. Recitation-type questions took up most of the teacher discourse at an average of 85.69, and these questions elicited lower-order responses (M=93.37) from students. The higher order responses were limited to on average 2.45 in this sample. Student-to-student interactions were minimal, and other constructs such as press for involvement and press for explanations or justifications were equally as rare (p. 17). Consequently, students' responses were taken up infrequently as object of discourse. Teachers did the majority of mathematical thinking, and too often students were asked to compute basic functions rather than think mathematically. This study also found that higher order questions and uptake of students' answers had positive impacts on student achievement, and furthermore, IRE patterns of interaction were negatively related to achievement (p. 22).

Classroom Connectivity Technology (CCT)

In classroom practice, three types of classrooms were found: high discourse, low discourse, and a hybrid of the two (Imm & Stylianou, 2012; Truxaw & Defranco, 2008). Imm and Stylianou (2012) found an "important relationship between cognitively demanding tasks and mathematical talk, and the power of discourse as a 'thinking device' as opposed to a mere conduit of knowledge" (p. 130). In social learning theory, these cognitively demanding tasks should take on the form of an authentic situation.

"Authentic situations" can be hard to come by in the classroom, but graphing calculators and classroom connectivity can provide an opportunity to visualize real-world applications. Vygotsky (1978) had the idea that tools mediate learning. These tools can consist of calculators or computers, but can also include cognitive tools such as language or algebraic symbols (Trouche & Drijvers, 2010). Graphing calculators are one type of calculator that has been shown to increase classroom discourse and student achievement in many studies. A meta-analysis performed by Ellington (2003) considered 42 studies comparing students with access to a graphing calculator to students who did not have access to this tool. When graphing calculators were introduced to a College Algebra classroom at a two-year college, Adams (1997) found they positively influenced classroom discourse. In particular, student-to-student interaction increased. For student achievement, Ellington (2003) found many studies with substantial gains, often in the 10-20 percentile points, in student achievement for those students using the graphing calculator. Half of these studies were in the collegiate classroom, and some of those found positive gains in their studies (Pankow, 1994; Quesada & Maxwell, 1994). Quesada and Maxwell (1994) found students who were taught with graphing calculators had significantly higher scores on a comprehensive common final exam than those that were taught without the graphing calculator. This study involved 710 participants in a pre-calculus class at a large university over three semesters. The topics in this pre-calculus class included polynomial, rational, exponential, and logarithmic functions and their applications which are also topics in our study. There were five experimental sections and eight control group sections, both groups made up of small class sizes and large class sizes during the three semesters. The experimental sections used graphing calculators whereas the control groups did not with both groups taking the same comprehensive common final exam. They found a statistically significant effect with using the calculators versus not using calculators and also found the mean test scores were significantly higher (Quezada & Maxwell, 1994).

Studies that are more recent also show the same types of gains (Lyublinskaya & Tournaki, 2011; Reznichenko, 2012). Reznichenko (2012) studied the effect on student achievement using graphing calculators to teach a college Intermediate Algebra class. There was one experimental section that was taught with graphing calculator enhanced instruction and the control group was taught by a method which did not include graphing calculators. Both groups took a pre- and post-test for student achievement. They concluded a significant difference in means ($F = 1.470$ and $p = .000$) between the two groups and the experimental group scored significantly higher (Reznichenko, 2012).

Another type of technology proven to show gains in student achievement in mathematics is a Classroom Response System (CRS). A CRS is any system that allows a face-to-face classroom of students to be polled and the instructor to receive immediate feedback. CRS have been found to increase student engagement (d'Inverno, Davis, & White, 2003; Graham, Tripp, Seawright, & Joeckel, 2007), make instructors aware of student understanding and more responsive in their instruction (Boyle & Nicol, 2003; Bullock et al., 2002; Davis, 2003; Dufresne, Wenk, Mestre, Gerace, & Leonard, 1996; Fies, 2005; Hall, Waitz, Brodeur, Soderheolm, & Nasr, 2002), give students the opportunity to become self-monitoring of their own understanding (Boyle, et al., 2001; Dufresne et al., 1996; Fies, 2005; Hall et al., 2002), improve communication in the classroom (Boyle & Nicol, 2003; Bullock et al., 2002; Dufresne et al., 1996; Fies, 2005; Mestre, Gerace, Dufresne, & Leonard, 1996), and increase student learning (Hall, Collier, Thomas, & Hilgers, 2005). Other studies have shown a significant learning achievement (Hall et al., 2005; Karaman, 2011; Morais, Barragues, & Guisasola, 2015), but in particular, an increase in mathematics achievement when a CRS was used during instruction (Dix, 2013; Jacobs, 2013).

The Jacobs (2013) study took place in a middle school setting for 7th and 8th grade students. The researchers wanted to see if there was a difference in mathematics achievement for those who had instruction using a CRS versus those without. They measured mathematics achievement using the Arizona Instrument to Measure Standards (AIMS) test which is a test mandated by the Arizona Department of Education to measure academic achievement in mathematics for students in grades 3-8 and grade 10. There were 416 students participating in the study. The researchers compared the result of the AIMS test for student receiving instruction with the CRS versus those students from previous years that did not have access to a CRS. The researchers found positive gains in achievement on the AIMS test for both 7th grade (p = .00000058) students and 8th grade (p = .00001131) students.

At postsecondary level, the Morais et al. (2015) study took place in a university calculus classroom with a total of 88 students in the treatment group and 86 students in the control group over 28 weeks. The control group received conventional teaching methods by an instructor outside the research study whereas the treatment group was instructed by one of the researchers using a CRS. The treatment group showed greater gains in learning with an average normalized gain value of .71 as compared to the control group's .25 gain value. Researchers chose the TI-Navigator™ system with the TI-Nspire™ CAS graphing calculators as the CRS for this study after acknowledging the pedagogical importance of discourse as inextricably linked with the TI-Navigator™ system. Figure 2-1 gives a visual depiction of this wireless system that connects each student calculator to a teacher computer.

Student calculators can be linked together using the TI-Navigator™ system which is a response system that connects all student graphing calculators to a teacher workstation. This classroom connectivity allows the teacher to track progress, offer instant student feedback, and promote problem solving activities. The TI-Navigator™ system is Texas Instruments extension of the audience response system which provides the student with problem-solving opportunities that instructors can take advantage of for discussing critical problem-solving strategies and approaches as well as the cognitive development of mathematical concepts.

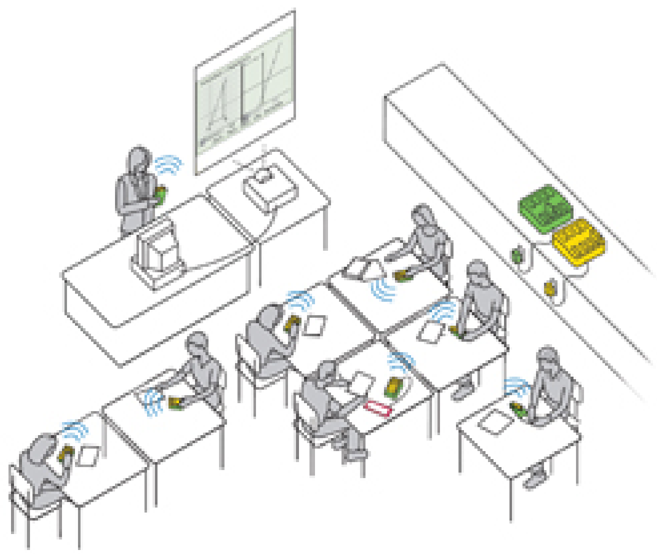


Figure 2-1. The wireless TI-Navigator™ system.

The TI-Navigator™ system offers an autonomous way of student engagement. Instructors can pose problems for students to work individually or in groups. All answers are sent to the main teacher workstation for immediate viewing for classroom discussion. If anonymity is of concern, instructors can turn off the identification of the calculator. It has been shown that students prefer not to reveal their identity when responding to in-class questions and anonymity is preferred (Freeman, Blayney, & Ginns, 2006). The TI-Navigator™ system offers Quick polls for immediate teacher insight into their students' comprehension of content. Quick polls offer an avenue for instructors to gauge student knowledge and, with this new teacher knowledge, can redirect instruction and discourse to suit student needs. Screen capture is another feature that encourages discourse. Student calculator screens can be simultaneously displayed for the teacher to encourage discussion like to compare and contrast graphs or to formulate the fundamentals of the equation of these graphs. The TI-Navigator™ system has been the subject of several project studies. The CCMS project aimed at improving the quality of discourse in the Algebra I classroom with the aid of the TI-Navigator™ system.

For this large study, 127 teachers from throughout the US and two provinces of Canada participated in a weeklong professional development seminar focused on the TI-Navigator™ system. The teacher participants were briefly introduced by the researchers to the idea of discourse theory practices with the TI-Navigator™ system, but there was no explicit training on how to implement the practice of discourse with the TI-Navigator™ system in the classroom. These teachers were videotaped periodically in their Algebra I classrooms and the videotapes were closely analyzed. There were a total of 1,761 students that participated in this project, and gains were found in Algebra I performance. Several studies that arose out of this project, but two are of particular interest in this paper.

Another CCMS study of interest, Owens et al. (2008), looked at 118 of these teachers from 28 US states and two Canadian provinces and data from 1,128 of the initial 1,761 students ranging from 7th to 10th grade were analyzed. This study examined the relationship between classroom connectivity and Algebra I student performance. There were three student-level measures. The first was an Algebra pretest and posttest. The second was a Student Beliefs About Mathematics survey measuring beliefs about mathematics (α = .82), confidence (α = .69), mathematics anxiety (α = .79), usefulness of mathematics (α = .82), and self-efficacy (α = .88). The third student-level measure was a Motivated Strategies for Learning Questionnaire (MSLQ) developed by Pintrich, Smith, Garcia, and McKeachie (1991) which measured student motivation and learning strategies. The three teacher-level measures included a Teacher Instructional Practice and Beliefs Survey (TIPBS), level of content coverage, and a telephone interview protocol to gauge the teacher belief of the level of use of technology and implementation of the strategy. The TIPBS measured school support (α = .79), familiarity of NCTM standards (α = .68), use of instructional technology (α = .86), reform classroom discourse (α = .73), strategy discussion (α = .85), explanations and justifications (α = .79), data analysis (α = .90), teacher efficacy (α = .80), and teacher beliefs about mathematics (α = .64). A statistically significant difference was found for the students in the treatment group in Algebra I performance after controlling for several variables. They also found a 14% mean learning gain when using the TI-Navigator™ system in the mathematics classroom, and the level of teacher knowledge about how students comprehend the material as a result of the TI-Navigator™ system use was positively related to student performance. This study also showed significant effect sizes from .19 to .37 in Algebra 1 student achievement over a three-year period (Irving et al., 2010).

The second CCMS study of interest, Pape et al. (2010), studied the classroom interactional patterns in a sample of 33 out of the 127 teachers in the larger sample from year one observations. They performed an in-depth examination into the teachers' questions, mathematical statements by both teacher and students, teachers' responses to these statements, non-mathematical talk, and use of the TI-Navigator™ system (p. 3). The same student measures from Owens et al. (2008) was also used in this study, but they focused particularly on classroom discourse. They examined 15 classroom observation constructs including types of questions, cognitive load, teachers' responses to student mathematic comments, IRE patterns, uptake of correct and incorrect answers, teacher press for explanation, non-instructional discourse, and technology use. Uptake of answers refers to critical exploration of an answer by having students explain why an answer is correct or incorrect, prompted through the instructor's directed questioning. Patterns like IRE are less favorable for student comprehension for they do not allow for uptake of correct and incorrect answers that provides scaffolding of knowledge. The researchers found that control teachers asked more recitation questions (p = .001) that elicited lower-order responses (p = .001) than did the treatment teachers. Pape et al. (2008) also found that higher order questions were associated with higher achievement in the Algebra I classrooms.

The Dougherty and Hobbs (2007) study focused on Algebra II in two public schools in Mississippi consisting of 363 student participants of which 210 were part of the experimental group. TI-84+™ calculators were given to all students, but the experimental class teachers were also given a TI-Navigator™ system to use each day for instruction. Analysis of the pre- and post-tests given to both groups of students revealed that they both improved their scores; however, the experimental group gains were statistically significant (p = .007).

While the Dougherty and Hobbs (2007) study and the CCMS project focused on high schools, Powers and Champion (2008) examined the TI-Navigator™ system use in the university College Algebra classroom. Their primary research interests included whether the TI-Navigator™ system promoted student engagement and increased student achievement. Four sections of College Algebra (n = 128) were sampled: two were control groups (no TI-Navigator™ system) and two were treatment groups (with TI-Navigator™ system). Two instructors, graduate teaching assistants, were assigned to one treatment class and one control class each. The results indicated the TI-Navigator™ system provided opportunities for student interaction and more informed feedback to instructors on student understanding. Unlike the CCMS study, they found no statistical difference in algebra performance. The authors did not divulge the nature of the professional development given to these two instructors except to indicate that they "learned the TI-Navigator™ software as part of the study" (p. 2).

No other study could be found that examined whether the TI-Navigator™ system affects student achievement in a two-year college mathematics classroom. The following study began with developing the two-year college mathematics instructors with effective discourse processes as a natural extension to classroom connectivity. Texas Instruments provided extensive professional development to the instructors that will be described in the next chapter.

CHAPTER 3
METHODOLOGY

This chapter details proposed methodology of the study, including the setting of the experiment, the characteristics of the participants, design of the study, data collection, and it presents a plan of analysis.

Experimental Setting

The study took place at a two-year college in a rural, 100-acre campus in north central Florida. In terms of enrollment, this college is considered one of the smallest colleges in the FCS; however, it serves five counties, one of the largest regions in the state spanning twice the size of Rhode Island. The serving region has no affluent centers, very high rates of poverty, a prevalence of low wage service industries, and extremely low populations. Due to economic distress and barriers to growth at the time of the study, the governor designated these five counties as a rural area of critical economic concern.

School Demographics

The average student is first generation, underprepared, part-time, employed, and older than traditional college age students. During the study's academic years 2009-2010 and 2010-2011, unduplicated headcount for students enrolled for at least one course were 5,674 and 5,666, respectively. Table 3-1 shows the total enrollment per semester for each term during the two-year period.

Tables 3-2, 3-3, and 3-4 are snapshots of the enrollment breakdowns for the fall term of that academic year. Since enrollment trends are steady, these snapshots would be a good indicator of yearly trends. Table 3-2 shows the steady enrollment by ethnicity typical for a rural college. This school setting has predominantly more Caucasians at approximately 83% and considerably less Hispanics at approximately 2.5% than the national average at 54% and 22% respectively. The African American population at this school is relatively the same as the national average of 6%.

Table 3-1. Enrollment by semester.

	Summer	Fall		Spring	
Year	Part-time	Full-time	Part-time	Full-time	Part-time
2009-2010	1,934	1,281	1,906	1,213	1,856
2010-2011	1,933	1,254	1,801	1,081	2,031

Table 3-2. Percent enrollment by ethnicity for fall term of the academic year.

Year	Caucasian	African American	Hispanic	Other
Fall 2009	83.7%	11.7%	2.4%	2.1%
Fall 2010	82.7%	12.7%	2.5%	2.1%

Table 3-3. Percent enrollment by age groups.

Year	<18	18–24	25-34	35≤
Fall 2009	12.2%	48.9%	21.6%	17.2%
Fall 2010	15.6%	46.4%	20.0%	18.0%

Table 3-3 shows the enrollment for age. Roughly 38% of the population is older than the traditional student. This rural school has a larger population of older students than the average two-year college in the nation at 27% of students age 25 year or over. Between 12% and 16% of students under 18 and were mainly dual enrollment students from the surrounding five counties.

Table 3-4 shows that for those older non-traditional students, the majority were attending college part-time whereas approximately 50% of those traditional students 18–24 attended part-time. Students younger than 18 are mainly attending part-time while also taking courses at their high school.

Table 3-5 depicts a college whose student population is mainly female (~67%) and that students attend on a part-time basis (~60%). These statistics have a 10% difference to the national averages. The gender gap nationwide at two-year colleges is 57% female and 43% male (AACC, 2015), but the difference between part-time and full-time students is the same when compared to the national average of 61% and 39%, respectively.

Table 3-4. Percent enrollment by age groups by full-time or part-time status.

	<18		18–24		25-34		35≤	
Year	Full	Part	Full	Part	Full	Part	Full	Part
Fall 2009	1.7%	10.5%	26.5%	22.4%	7.3%	14.3%	4.7%	12.5%
Fall 2010	2.4%	13.2%	25.2%	21.2%	8.1%	11.8%	5.3%	12.7%

Table 3-5. Percent enrollment by gender and enrollment status.

	Gender		Status	
Year	Male	Female	Full-time	Part-time
Fall 2009	32.9%	67.1%	40.2%	59.8%
Fall 2010	34.0%	66.0%	41.0%	59.0%

The college demographics have remained relatively the same for the two years of the experiment. These statistics align with the two-year college student population.

Design of Study and Evaluations

This ex-post facto study was part of a larger quasi-experimental study by Stephen Pape of Johns Hopkins University to examine discourse patterns and the impact the TI-Navigator had on these discourse patterns in a two-year college mathematics classroom as well as student attitudes toward mathematics. There were 964 total participants with 44 total sections in year one and 41 total sections in year two spanning the arithmetic to college algebra sequences.

This particular static-group comparison study used quantitative data readily available from student results gathered during the larger Pape study. All traditional sections of intermediate algebra and college algebra were considered for the study. There were 12 college algebra and 11 intermediate algebra sections in year one with 12 and 12 sections, respectively, in year two. This is not a true experimental design in which random sampling could be implemented. Students self-selected into course sections that were traditional, compressed video, or internet based. All sections were taught by faculty participants; however, sections taught through compressed video or the internet were not considered for this study based on confounding variables that would not be comparable to a traditional setting. For instance, students enrolling in internet courses or courses delivered through compressed video would be unable to physically utilize the TI-Navigator™ system remotely. This approach did not allow for a control group typical in a true experiment so results should be viewed only in terms of correlation rather than causality.

This static-group comparison study was to determine whether there was a significant difference between the test scores and course grades for those student participants in year one versus those students in year two when CCT was used as an instructional tool. The four research questions of this study are as follows:

1. Is there a significant difference in student scores on the Intermediate Algebra departmental final exam from year one to year two when the CCT was used as an instructional strategy?
2. Is there a significant difference in student grades in Intermediate Algebra from year one to year two when the CCT was used as an instructional strategy?
3. Is there a significant difference in student scores on the College Algebra departmental final exam from year one to year two when the CCT was used as an instructional strategy?

4. Is there a significant difference in student grades in College Algebra from year one to year two when the CCT was used as an instructional strategy?

Since the literature showed the importance of discourse coupled with the TI-Navigator™ system, professional development in discourse theory was needed for instructors in order to fully use the TI-Navigator™ system in the classroom. Year one was spent providing this professional development to the instructors and in year two the TI-Navigator™ systems were employed as an instructional tool in all MAT 1033 and MAC 1105 traditional classrooms.

The Instructor Training

For each year of the study, the university researcher and a Texas Instruments training representative provided professional development to each participating instructor. The first year provided 12 full-day sessions, and the second year had five full-day sessions. Thought was given as to whether these sessions should be concentrated in a small period of time, but it was believed the instructors should reflect upon these sessions over spans of time. For the first year, the research team decided to break up the 12 full-day sessions throughout the academic year.

Beginning in the fall 2009 semester, mathematics instructors were immersed in discourse pedagogy for two days. The professional development was spread throughout the fall semester, starting with two full days during the week prior to the start of fall semester classes. An overview of discourse theory was discussed during the first day with instructor self-reflection on their own teaching practices. Content covered during this professional development included authentic versus recitation questions; levels of cognitive loads whether lower order versus higher order; uptake of correct and incorrect responses; teacher press for student elaboration, explanation, and justifications; and finally, the use of scaffolding. Videos of instructors demonstrating these constructs were viewed and discussed on the following day. Instructors were asked to further reflect on their own teaching practices and how they could improve their techniques. An assignment prompted instructors to design a line of effective questions, or lesson plans, to implement in their own classrooms. Lesson plans were discussed at the next professional development day scheduled in October, 2009. Each instructor was asked to share his or her reflection piece as well as a lesson plan. Peer critiques were offered to help instructors revise their plans before the last professional development day of the fall semester. With student and instructor permission, researchers videotaped two classroom teaching sessions per instructor for discourse practices to be analyzed.

Since instructors were familiar with only the TI-83 calculators, Texas Instruments provided a two-day workshop in December 2009, on the TI-Nspire™ calculators. Instructors took home the software over the holiday break to practice their knowledge of the TI-Nspire™ calculators before returning for the spring semester for three additional days of training. Those three days focused on the TI-Navigator™ software that provided the wireless link of all the student calculators. Unfortunately, the TI-Nspire™ CAS calculators were not available at the time of training. Expected receipt of those calculators was in the middle of spring 2010.

The spring 2010 semester began with three days of training on the TI-Navigator™ system from TI prior to the start of classes. A trainer from TI provided intensive professional development on the technical and practical aspects of the system. Three more professional development days followed through the remainder of the semester to tie the concepts of discourse theory with the classroom connection of the TI-Navigator™ system. Instructors began to build lesson plans that tied effective questioning and applications using the TI-Navigator™ system to be used in their classes starting in fall 2010.

During the summer of 2010, a university researcher and two graduate students who studied under the direction of the university researcher helped develop lessons focused on Intermediate Algebra and College Algebra content. They incorporated the teaching methodology to help instructors who were less technically savvy with creating their own lessons using this technology. These lessons were put on the college's intranet for all instructors to access. Six TI-Navigator™ systems equipped with 25 TI-Nspire™ CAS calculators each were placed into six classrooms. These systems along with their calculators were locked in a cart, which remained in the classroom.

Technical difficulties were discovered that prevented use of these systems during the spring 2010 semester. The software lacked the ability to save information on the college's intranet and only allowed information to be saved on the local drive. The college's technology infrastructure did not allow for information to be stored on the local drive. The purchase of laptops alleviated this problem and full implementation started in the fall of 2010. Instructors needed to transport their laptops, but the TI-Navigator™ systems were stationary in individual classrooms. Instructors were encouraged to begin incorporating these methodologies into their classroom, but some were more eager to use the new technology than others.

Professional development continued as a support mechanism in the 2010-2011 academic year. Five days were spread throughout the school year to alleviate concerns, frustration, and technical difficulties instructors were experiencing. In the fall, an analysis of their discourse practices from the videotapes recorded last school year was provided to each instructor. Teaching practices were recorded in the videotapes, and instructors received summary statistics associated with their classroom observation. Analysis performed by the university researcher reviewed actual classroom practices for frequency counts of IRE, lower-order, and higher-order questions. Lower-order and higher-order questions were gauged by the response the instructor accepted as the participant answer. Upon review of classroom analysis, most instructors recognized that their belief they were already practicing the methodologies behind the QEP was exaggerated and that they needed to alter classroom practices or strengthen their commitment to employ new methodologies. Additional instructor support continued through the 2010-2011 school year during which two graduate students assisted instructors in their implementation of the TI-Navigator™ system by providing insight into classroom opportunities for questioning and suggestions for changes in lessons to enhance student learning.

Of the original nine instructors, five remain who have participated in two years of professional development. One instructor passed away, one moved out of the state, one changed careers, and the last dropped out for personal reasons.

The Intervention

During the 2009-2010 school year, students did experience some changes in their instructor's pedagogical approach to teaching. While instructors were going through the training in discourse, students were experiencing a slight change in the way instructors asked questions in class; however, usually only one or two students would answer the questions posed. Most students did not participate in classroom discussion.

There was little uptake of incorrect answers. Instructors also did not press for all student involvement during class, so instructors were unaware of student content knowledge as a whole class.

In the 2010-2011 school year, the TI-Navigator™ systems were employed in all the mathematics classrooms for instructional purposes. There was a learning curve for students using this new technology, and some student participants were hesitant at first; however, instructors discussed classroom norms and class expectations with students. By week two, students were entering classrooms and immediately picking up their calculators from the calculator cart and logging into the TI-Navigator™ system before class even started. This became a classroom norm for most classes. Some instructors noted a seamless transition into the start of class with all students logged into the system already before class started. Some classes would begin class with a quiz document sent to the students' calculators. Instructors would press for all student involvement by periodically saying how many students still needed to submit. Once all quizzes were submitted, the instructor would collect the quizzes through the software and display the results on the projection screen. The display would consist of the frequency counts of either the multiple choice answers or, if it were a free response quiz, a frequency count of all the answers provided by students. Students would see the aggregated results on the screen. The instructor would ask questions such as "How would someone come up with this answer?" Here, students made conjectures about possible ways of getting a particular answer or students would explain how they derived their own answer. Students would volunteer when they got answers wrong. Instructors stated students' willingness to admit to being wrong was a noticeable change in classroom norms.

As instructors lectured on new material, instructors would send out Quick Polls to the students for immediate feedback to assess whether the entire class understood the content covered. This is how instructors were able to uptake answers and press for deeper understanding through using the calculators. The uptake of correct or incorrect answers through the Quick Polls gave instructors the ability to know where their class stood as a whole and this was possible with the Quick Polls. The TI-Navigator™ system enhanced the instructors' ability to ask higher order questions and the students' opportunity to give deeper insight into their thought process.

Another approach to delivery of new material was to send documents to students' calculators for them to work through. In one class, a lesson on the standard quadratic function was sent presenting sliders for *h*, *k*, and *a*. Students were asked to think about how the three parameters would help them to know the vertex of a parabola and its direction on the graph. The instructor would randomly select a student to be the student presenter and display their calculator on the projection screen. This student changed the *a* from positive to negative and stated that doing so was the same as flipping an equation across the x-axis. While watching the student manipulate the values of *h* and *k*, students noted the impact of the location of the vertex. The instructor was able to make connections regarding transformations from this lesson to transformation lessons from previous chapters. At the end of class, students would return the calculators to the calculator cart for battery charging.

Most instructors' teaching styles changed from a teacher-directed approach to a student-directed approach through the year. The relationship between instructor and students in these classes changed with more in-depth focusing of content. Students felt more comfortable talking and exposing their incorrect perceptions for clearer understanding of content. Some instructors' classroom norms changed with the use of technology while instructors established the norm of using the calculators each day for quizzes or quick polls. It helped the instructors get used to teaching with the calculator, and it helped the students get acclimated with the technology by having it in their hands every day. It is extremely important to note that the intervention experienced by the students was a combined package of the training given to their instructors in discourse theory and the TI-NavigatorTM system. Without these coupled together, the student experience would most likely be different.

The Department Final Exams

There were no changes to the departmental final exam in MAT 1033 (see Appendix A) from year one to year two; however, there were some changes to the departmental final exam in MAC 1105 (see Appendices B & C). Some of those changes were significant enough to warrant removal of one question. That question, number 27 from both years, was in regard to graphing of a logarithmic function. From year one, the question asked students to graph the function $f(x)=\log_3(x)+2$ and the students had to pick which answer choice would be the graph of $f(x)$ (see Appendix B, question 27). In year two, the question prompt changed to a more conceptual question. This question consisted of a logarithmic graph, and students were asked to pick the function (see Appendix C, question 27). This question was thrown out of the data analysis because it was a substantive change in question-type that required a significantly different level of understanding to answer. The percentage of students getting problem 27 correct in year one was 67% dramatically dropping down to 24% in year two, showing it was an unfair question to compare.

Data Collection

Survey data were collected at the beginning of each semester, and final exam and grade data were collected at the end of each semester. The departmental final exams consisted of multiple choice items, and scantrons were used for data collection. The scantrons were then scanned for data analysis and scores. The overall final exam scores were noted as well as the participant final grades in each class.

There were 520 students who participated in the study; 314 of these participants enrolled in Intermediate Algebra, but seven participants had retaken the class within the two-year period. Likewise, for College Algebra 297 participants enrolled with eight participants repeating the course within this period. Of the participants who repeated, their second attempt data was removed from the sample so there will be no repeated trials in this sample. Ninety-one of the 520 participants took both Intermediate Algebra and College Algebra within the time period of the study. The breakdown of enrollment in the study is depicted in Table 3-6.

Table 3-6. The enrollment in the study per term.

	2009–2010		2010-2011		
Course	Fall	Spring	Fall	Spring	Total
MAT 1033	89	59	99	67	314
MAC 1105	85	64	59	89	297
Total	174	123	158	156	

During the two-year period, 169 (32.5%) were male and 343 (66%) participants were female, and eight participants did not disclose their gender. These statistics are equivalent to the school population, and somewhat close to the national two-year college statistics of 43% male and 57% female (AACC, 2015). Tables 3-7 and 3-8 break down the gender statistics in MAT 1033 and MAC 1105, respectively.

Table 3-7. Participant gender breakdown for MAT 1033 per term.

	2009-2010				2010-2011			
	Fall		Spring		Fall		Spring	
Course	n	%	n	%	n	%	n	%
Female	60	67.4	35	59.3	70	70.7	45	67.2
Male	29	32.6	22	37.3	28	28.3	22	32.8
Undeclared	0	-	2	3.3	1	1.0	0	-

Table 3-8. Participant gender breakdown for MAC 1105 per term.

	2009-2010				2010-2011			
	Fall		Spring		Fall		Spring	
Course	n	%	n	%	n	%	n	%
Female	53	62.3	47	73.4	40	67.8	56	62.9
Male	30	35.3	17	26.6	18	30.5	31	34.8
Undeclared	2	2.4	0	-	1	1.7	2	2.2

Table 3-9. Participant ethnic breakdown in MAT 1033 per term.

	2009-2010				2010-2011			
	Fall		Spring		Fall		Spring	
Ethnicity	n	%	n	%	n	%	n	%
Caucasian	64	71.9	30	50.8	83	83.8	55	82.1
African-American	3	3.4	5	8.5	13	13.1	4	6.0
Hispanic	3	3.4	0	-	2	2.0	4	6.0
Asian	0	-	0	-	0	-	0	-
Multiracial	1	1.1	0	-	0	-	2	3.0
Other	0	-	0	-	1	1.0	0	-
Undeclared	18	20.2	24	40.7	0	-	2	3.0

The ethnic breakdown of the sample was 70.0% Caucasian, 7.3% African American, 3.7% Hispanic, .6% Asian, and 17.1% who did not identify. An additional 1.2% of the sample identified themselves as multiracial. Tables 3-9 and 3-10 depict the ethnicity of the participants in MAT 1033 and MAC 1105, respectively, per term. These statistics were also equivalent to the school population. Nationwide, however, the percentages are different with 50% Caucasian, 14% African American, 21% Hispanic, and 6% Asian (AACC, 2015). This school sample is a homogenous sample, which limits our ability to generalize the study. The researcher suspects the lack of ethnic declaration in the first year was due to mistrust of collection of these data.

Table 3-10. Participant ethnic breakdown in MAC 1105 per term.

	2009-2010				2010-2011			
	Fall		Spring		Fall		Spring	
Course	n	%	n	%	n	%	n	%
Caucasian	67	78.8	21	32.8	49	83.1	67	75.3
African-American	4	4.7	0	-	3	5.1	12	13.6
Hispanic	3	3.5	4	6.3	3	5.1	5	5.6
Asian	1	1.2	0	-	0	-	2	2.2
Multiracial	0	-	1	1.6	2	3.4	1	1.1
Other	0	-	0	-	1	1.7	0	-
Undeclared	10	11.7	38	59.4	1	1.7	2	2.2

The age breakdown of the sample was 11.9% were under 18 years of age, 44.2% were between 18 – 24-years old, 14.4% were between 25 – 34 years old, and 13.7% were 35 or older. During the study,15.8% did not disclose their age. Tables 3-11 and 3-12 depict the age of the participants per term for MAT 1033 and MAC 1105, respectively. Roughly 30% of all participants taking MAT 1033 are 25 or over. These participants most likely have not taken mathematics in at least 7 years. The spring

2010 term saw a greater number of participants opting out of revealing their demographic information for ethnicity and age. Matter of fact, a much larger group opted out for the 2009-2010 school year than the 2010-2011 school year. This researcher surmises that students were skeptical at first until word got out about the research project.

Table 3-11. Participant age breakdown for MAT 1033 per term.

	2009-2010				2010-2011			
	Fall		Spring		Fall		Spring	
Age group	n	%	n	%	n	%	n	%
<18	7	7.9	0	-	4	4.0	1	1.5
18-24	34	38.2	22	37.3	61	61.6	38	56.7
25-34	10	11.2	10	16.9	17	17.2	13	19.4
35≤	20	22.5	3	5.1	17	17.2	15	22.4
Undeclared	18	20.2	24	40.7	0	-	0	-

Table 3-12. Participant age breakdown for MAC 1105 per term.

	2009-2010				2010-2011			
	Fall		Spring		Fall		Spring	
Age group	n	%	n	%	n	%	n	%
<18	9	10.6	3	4.7	2	3.4	2	2.2
18-24	48	56.5	17	26.6	40	67.8	49	55.1
25-34	14	16.5	3	4.7	12	20.3	22	24.7
35≤	7	8.2	5	7.8	4	6.8	16	18.0
Undeclared	7	8.2	36	56.3	1	1.7	0	-

The equivalencies of the group participants can only be approximated due to the college losing some data during a data conversion to a new student information system. Of the year one student participants for MAT 1033 for which data could be retrieved, 57% tested into the lowest level of mathematics, arithmetic (MAT 0012), and 27% tested into elementary algebra (MAT 0024), and the remaining 17% tested into MAT

1033. Year two participants were quite similar with 62%, 28%, and 9% testing into MAT 0012, MAT 0024, and MAT 1033, respectively. Other information regarding MAT 1033 student participants include 67% of these student in year one and 69% in year two took the prerequisite MAT 0024 course. Furthermore, 27% of MAT 1033 student participants in year one and 21% in year two were repeating the class after prior failed attempts. Finally, 30% of students from year one participants and 27% of year two participants waited over a year to register for this course from their previous mathematics course taken.

Of the year one student participants for MAC 1105 for which data could be retrieved, 77% tested into the lowest level of mathematics, arithmetic (MAT 0012), and 7% tested into elementary algebra (MAT 0024), and 10% tested into intermediate algebra (MAT 1033), and the remaining 7% tested into MAC 1105 when they first enrolled in college. Year two participants were quite similar with 70%, 9%, 13%, and 8% testing into MAT 0012, MAT 0024, MAT 1033, and MAC 1105, respectively. Other information regarding MAC 1105 student participants include 70% of these student in year one and 72% in year two took the prerequisite MAT 1033 course. Furthermore, 27% of MAC 1105 student participants in year one and 24% in year two were repeating the class after prior failed attempts. Finally, 30% of students from year one participants and 34% of year two participants waited over a year to register for this course from their previous mathematics course taken.

With the data that were able to be retrieved, the student participant groups for MAT 1033 and MAC 1105 were approximately equivalent from year one to year two of the study. A true comparison could not be made due to the fact that data were missing.

The Analysis

This static-group comparison design study looked at final grades and departmental final exam scores for the targeted classes from fall 2009 through spring 2011, excluding summer terms. These data were organized by year one of the professional development and then year two for the implementation of the TI-Navigator^{TM} system equipment. Student participants in years one and two were strictly self-selecting, meaning they registered themselves into the sections and these participants were not randomly assigned. All sections taught by the faculty participating in the professional development were chosen for the study. Students registering for sections taught in a non-traditional manner, like compressed video or internet, were not selected as part of this study. Students that registered for the traditional section of College Algebra or Intermediate Algebra were asked if they wished to participate in the study. Those students that signed the consent forms are reported in these results.

At the end of each semester, all student participants took the departmental final exam that consisted of multiple-choice questions (see Appendices A, B and C). Data of participant age, ethnicity, gender, final course grade, and departmental final exam scores were collected and analyzed for year one and year two participants.

All research questions were first turned into hypotheses questions and the null and alternative hypotheses were determined. To answer the first and third hypotheses, a t-test analysis, commonly suggested for a static-group comparison design, involving departmental final exam results determined whether there was a difference in scores between the year one group and the year two group in both MAT 1033 and MAC 1105. An $\alpha = .01$ was set for the significance level for hypotheses 1 and 3.

To answer the second and fourth hypotheses, a test of the course grades between the year one group and the year two group was made for MAT 1033 and MAC 1105. It was thought that the year two participants would be more engaged with their learning, consequently, producing a sample that would have more participants passing the course. Grades were coded similar to how grades are coded for grade point averages. An A was coded as 4, B+ as 3.5, B as 3, C+ as 2.5, C as 2, D+ as 1.5, D as 1, and an F as 0. The means of these grades were calculated and a significance level of $\alpha = .05$ was set for the analysis.

Limitations

The limitations of the study consisted of (a) student population, (b) school environment with researcher bias, and (c) the sampling method.

The Student Population

This study was performed at a rural two-year college where there is a rather homogenous population of student participants. As a result, ethnicities and socio-economic status of the participants were not considered when the data were analyzed, limiting the generalizability of the study. Also, most students at this two-year college have outside responsibilities that go beyond just the classroom. The influences of their work responsibilities and family responsibilities may have negatively affected their performance in the class. Too much data were missing to be able to give a more in-depth synopsis of the group equivalencies. The college's student information system was changed between fall 2009 and spring 2010. In the process, some data did not transfer over correctly causing background information that may have been more insightful missing.

The School Environment with Researcher Bias

This study took place over one school setting in which the researcher was employed as a mathematics instructor. Some of student participants may have been familiar with the researcher, which may have influenced their performance. Also the researcher held an additional administrative role at the college. The researcher had administrative duties such as scheduling of classes and handling student complaints. Other instructors may have been influenced by their relationship with the researcher. Therefore, the performance of both the instructors and some of the participants may have been influenced by their relationship with the researcher instead of the TI-Navigator™ system technology. The instructors also have different instructional styles and grading criteria that could influence the final course grades of these students.

Sampling Method and Selection Bias

A limitation also occurred in the sampling of the participants. Participants self-selected and registered for their classes before the semester began, so it was not a random assignment. Not all students registered for each section elected to participate in the study, but they remained in the class. As a consequence to the self-selection, treatment sections had small and unequal sample sizes, which could make significant differences hard to detect with the ANOVA and limited the study to grouping the students by year. There is also a possibility that group score and grade differences from year one to year two are due to preexisting group differences rather than the effect from the intervention. Also, causal estimates were not considered for this study. The sampling method and sample size would lead to unreliable results. Data were missing to make solid conclusions on cause.

CHAPTER 4
DATA ANALYSIS

Introduction

The objective of this study was to see if using CCT such as the TI-Navigator™ system would significantly impact student grades and scores on the departmental final exams for both MAT 1033 and MAC 1105 in a two-year college classroom. This chapter will present the results from this study by starting with the hypotheses used, the description of the sample participants, and finally the findings of the analysis.

Hypotheses

This study focused on whether using classroom connectivity in terms of the TI-Navigator™ system would increase departmental final exam results as well as final grades in both MAT 1033 and MAC 1105. There were four research questions for this study. They were

1. Is there a significant difference in student scores on the Intermediate Algebra departmental final exam from year one to year two when the CCT was used as an instructional strategy?
2. Is there a significant difference in student grades in Intermediate Algebra from year one to year two when the CCT was used as an instructional strategy?
3. Is there a significant difference in student scores on the College Algebra departmental final exam from year one to year two when the CCT was used as an instructional strategy?
4. Is there a significant difference in student grades in College Algebra from year one to year two when the CCT was used as an instructional strategy?

These research questions resulted in the following null hypotheses that were tested:

$H1_0$: There is no significant difference in the mean student scores on the MAT 1033 departmental final exam from year one without CCT to year two with CCT as an instructional strategy.

$H2_0$: There is no significant difference in the mean MAT 1033 course grades from year one without CCT to year two with CCT as an instructional strategy.

$H3_0$: There is no significant difference in the mean student scores on the MAC 1105 departmental final exam from year one without CCT to year two with CCT as an instructional strategy.

$H4_0$: There is no significant difference in the mean MAC 1105 course grades from year one without CCT to year two with CCT as an instructional strategy.

Detailed Analysis

Data were collected each semester by the researcher. For the departmental final exam, scantrons were scored by a scantron reader. Student scores were then inputted into a Microsoft Excel spreadsheet by the researcher. Scores were checked again to make sure of their accuracy. They were organized using a Microsoft Excel spreadsheet and imported into SPSS Statistics 23. The data analysis was then computed using SPSS Statistics 23.

Research Question 1

The first research question focused on success in the MAT 1033 department final exam (see Appendix A) which consisted of 26 multiple choice questions covering the topics in the course. The question is whether there was a difference in student scores from year one to year two when CCT was introduced as an instructional strategy in MAT 1033. The TI-Nspire™ CAS graphing calculators associated with the CCT were not allowed to be used on the departmental final exam. Students were allowed to use their own scientific calculators, which do not have the graphing capabilities of the TI-Nspire™ CAS. The question was determined to be: Is there a significant difference in student scores on the Intermediate Algebra departmental final exam from year one to year two when the CCT was used as an instructional strategy?

The question was turned into the following null and alternative hypotheses:

$H1_0$: There is no significant difference in the mean student scores on the MAT 1033 departmental final exam from year one without CCT to year two with CCT as an instructional strategy.

$$H1_0:\ \mu_1 - \mu_2 = 0$$

$H1_a$: There is a significant difference in the mean student scores on the MAT 1033 departmental final exam from year one without CCT to year two with CCT as an instructional strategy.

$$H1_a:\ \mu_1 - \mu_2 \neq 0$$

The general statistics for the exam scores in the study are listed in Table 4-1. The mean scores on the departmental final exam for MAT 1033 increased from 68% in year one to 73.3% in year two. The standard deviations were relatively the same at 16.1% in year one and 17.1% in year two.

Table 4-1. General statistics for each year in MAT 1033 departmental final exam.

Year	*n*	*M*	*SD*	*SE*
2009-2010	148	68.02	16.082	1.322
2010-2011	166	73.33	17.092	1.327

Table 4-2. *t*-test for equality of means in MAT 1033 departmental final.

Variances	*t*	*df*	Sig (2-tail)	Mean diff	*SE*	99% CI
Equal	-2.823	312.0	0.005	-5.305	1.879	(-10.18, -0.43)
Unequal	-2.833	311.1	0.005	-5.305	1.873	(-10.16, -0.45)

The Levene's test for equality of variances revealed an $F = 0.297$ with a *p*-value of .586. We can retain the null hypothesis that the variances are equal and assume the variances are equal so the *t*-test for independent mean samples can be performed. The results from the *t*-test for differences in the independent sample means are shown in Table 4-2. This test was performed with an $\alpha = .01$ for the significance level.

The results from the *t*-test for equality of means gives a $t = -2.823$ with a *p*-value = .005. The critical *t*-value for 312 degrees of freedom and an $\alpha = .01$ is approximately 2.592. This test indicates that we should reject the null hypothesis in support of the alternative hypothesis that the mean scores in the departmental final exam in MAT 1033 are different when CCT was used as an instructional strategy. The 99% confidence interval indicates that the difference in means will range between (-10.18, -0.43) showing the year two departmental final exam scores are greater than the year one scores. These results are statistically significant at the $\alpha = .01$ level. Since there was a significant difference finding, the effect size was calculated. The Cohen's *d* effect size was $d = .32$, which indicates a small effect.

Research Question 2

The second research question was concerning the final course grades in MAT 1033. The question is whether there is a difference in student final course grades when CCT was introduced as an instructional strategy in MAT 1033. The question was determined to be: Is there a significant difference in student grades in Intermediate Algebra from year one to year two when the CCT was used as an instructional strategy?

$H2_0$: There is no significant difference in the mean MAT 1033 course grades from year one without CCT to year two with CCT as an instructional strategy.

$$H2_0: \mu_1 - \mu_2 = 0$$

$H2_a$: There is a significant difference in the mean MAT 1033 course grades from year one without CCT to year two with CCT as an instructional strategy.

$$H2_a: \mu_1 - \mu_2 \neq 0$$

The researcher collected the participants' grades into a Microsoft Excel file from the college's internal grade management system. The grades were then coded as follows: A as a 4, B+ as a 3.5, B as a 3, C+ as a 2.5, C as a 2, D+ as a 1.5, D as a 1, and an F as a 0. The mean of these grades for each year was calculated. The general statistics for the participant course grades for MAT 1033 are listed in Table 4-3. The mean grades were 2.44 in year one and 2.60 in year two which are close to the C+ range. The standard deviation for each year is relatively large at 1.2, which is equivalent to a whole grade level.

Table 4-3. General statistics for each year in MAT 1033 course grades.

Year	*n*	*M*	*SD*	*SE*
2009-2010	148	2.439	1.256	0.103
2010-2011	166	2.599	1.211	0.094

The Levene's test for equality of variances revealed an $F = 0.156$ with a *p*-value of .693. We should retain the null hypothesis that the variances are equal. We can assume the variances are equal so the *t*-test for independent mean samples can be performed. The results from the *t*-test for differences in the independent sample means are shown in Table 4-4. This test was performed with an $\alpha = .05$ for the significance level.

Table 4-4. *t*-test for equality of means in MAT 1033 course grades.

Variances	*t*	*df*	Sig (2-tail)	Mean diff	*SE*	95% CI
Equal	-1.150	312.0	0.251	-0.160	0.139	(-0.434, 0.114)
Unequal	-1.147	305.0	0.252	-0.160	0.140	(-0.435, 0.115)

The results from the *t*-test for equality of means gives a $t = -1.15$ with a *p*-value = .251 indicating that we should retain the null hypothesis. The critical *t*-value for 312 degrees of freedom and an $\alpha = .05$ is approximately 1.968, so we can conclude the means remained the same. The 95% confidence interval (-0.434, 0.114) indicates that there was no difference given that zero difference remains in that interval. There was no statistically significant difference in grades at the $\alpha = .05$ level.

Research Question 3

The third research question was concerning success in MAC 1105 departmental final exam (see Appendices B & C). The exam originally consisted of 31 multiple choice questions covering the topics of College Algebra, but was changed from year one to year two. The instructors chose to change the questions to reflect a more conceptual thinking instead of rote calculations by the students. After careful review, the change in problem 27 was determined too dramatic and acted as an outlier of the data. The percentage of students getting problem 27 correct in year one was 67%, but after the change in year two, the percentage of student correctly answering problem 27 dramatically dropped to 24%, showing it was an unfair question to compare. This question was thrown out of the data analysis. The analysis covers the success of 30 questions of the departmental final exam.

The research question is whether there is a difference in student scores when CCT was introduced as an instructional strategy in MAC 1105. Like MAT 1033, the TI-Nspire™ CAS graphing calculators associated with the CCT were not allowed to be used on the departmental final exam. Students were allowed to use their own scientific calculators, which do not have the graphing capabilities of the TI-Nspire™ CAS. The question was determined to be: Is there a significant difference in student scores on the College Algebra departmental final exam from year one to year two when the CCT was used as an instructional strategy?

These questions were turned into the following null and alternative hypotheses:

$H3_0$: There is no significant difference in the mean student scores on the MAC 1105 departmental final exam from year one without CCT to year two with CCT as an instructional strategy.

$$H3_0:\ \mu_1 - \mu_2 = 0$$

H3a: There is a significant difference in the mean student scores on the MAC 1105 departmental final exam from year one without CCT to year two with CCT as an instructional strategy.

$$H3_a:\ \mu_1 - \mu_2 \neq 0$$

The general statistics for the exam scores in the study are listed in Table 4-5. The mean score increased from 69.5% in year one to 75.4% in year two. Both the standard deviations and the standard error were relatively the same but decreased from 14.4 to 13.6 and 1.18 to 1.12, respectively.

Table 4-5. General statistics for each group in MAC 1105 departmental final exam.

Year	*n*	*M*	*SD*	*SE*
2009-2010	149	69.46	14.443	1.183
2010-2011	148	75.37	13.644	1.122

The Levene's test for equality of variances revealed an F = 1.356 with a *p*-value of .245. The null hypothesis was retained that the variances are equal. We can assume the variances are equal so the *t*-test for independent mean samples can be performed. The results from the *t*-test for differences in the independent sample means are shown in Table 4-6 was performed with an α = .01 for the significance level.

Table 4-6. *t*-test for equality of means in MAC 1105 departmental final.

Variances	*t*	*df*	Sig (2-tail)	Mean diff	*SE*	99% CI
Equal	-3.624	295.0	0.000	-5.909	1.631	(-10.14, -1.68)
Unequal	-3.624	294.3	0.000	-5.909	1.630	(-10.14, -1.68)

The critical *t*-value for 295 degrees of freedom and α = .01 is approximately 2.592. The results from the *t*-test for equality of means gives an observed *t*-value *of* -2.823 with a *p*-value = .005 indicating that we should reject the null hypothesis in support of the alternative hypothesis since 2.823>2.592. The 99% confidence interval indicates that the difference in means will range between (-10.14, -1.68) showing the year two final exam scores are greater than the year one scores. These results are statistically significant at the α = .01 level. Since there was a significant difference finding, the effect size was calculated. The Cohen's *d* effect size was *d* = .42, which indicates a moderate effect.

Research Question 4

The fourth research question concerned the final course grades in MAC 1105. The question is whether there is a difference in student final course grades when CCT was introduced as an instructional strategy in MAC 1105. The question was determined to be: Is there a significant difference in student grades in College Algebra from year one to year two when the CCT was used as an instructional strategy?

$H4_0$: There is no significant difference in the mean MAC 1105 course grades from year one without CCT to year two with CCT as an instructional strategy.

$$H4_0: \mu_1 - \mu_2 = 0$$

$H4_a$: There a significant difference in the mean MAC 1105 course grades from year one without CCT to year two with CCT as an instructional strategy.

$$H4_a: \mu_1 - \mu_2 \neq 0$$

The researcher collected the participants' grades into a Microsoft Excel file from the college's internal grade management system. The grades were then coded as follows: A as a 4, B+ as a 3.5, B as a 3, C+ as a 2.5, C as a 2, D+ as a 1.5, D as a 1, and an F as a 0. The mean of these grades for each year was calculated. The general statistics for the participant course grades for MAT 1033 are listed in Table 4-7. The results were similar to those in MAT 1033 mean course grades. The mean MAC 1105 course grades were 2.53 in year one and 2.50 in year two which are close to the C+ range. The standard deviation for each year is relatively large at 1.2 which is equivalent to a whole grade level.

Table 4-7. General statistics for each year in MAC 1105 course grades.

Year	*n*	*M*	*SD*	*SE*
2009-2010	149	2.530	1.201	0.098
2010-2011	148	2.497	1.237	0.102

The Levene's test for equality of variances revealed an $F = 0.149$ with a *p*-value of .700. The null hypothesis was retained that the variances are equal. We can assume the variances are equal so the *t*-test for independent mean samples can be performed. The results from the *t*-test for differences in the independent sample means are shown in Table 4-8 was performed with an $\alpha = .05$ for the significance level.

Table 4-8. *t*-test for equality of means in MAC 1105 course grades.

Variances	*t*	*df*	Sig (2-tail)	Mean diff	*SE*	95% CI
Equal	0.237	295.0	0.813	0.034	0.142	(-0.245, 0.312)
Unequal	0.237	294.6	0.813	0.034	0.142	(-0.245, 0.312)

The results from the *t*-test for equality of means gives a $t = 0.237$ with a *p*-value = .813 indicating that we should retain the null hypothesis. The critical *t*-value for 295 degrees of freedom and an $\alpha = .05$ is approximately 1.968 so we can conclude the means remained the same. The 95% confidence interval (-0.245, 0.312) indicates that there was no difference given that zero difference remains in that interval. There was no statistically significant difference in grades at the $\alpha = .05$ level.

Summary

In this research study, four research questions were analyzed using IBM SPSS Statistics 23. Those questions were measured using course grades and scores on the departmental final exams from the Intermediate Algebra and College Algebra classes. The year one group consisted of students registered for MAT 1033 and MAC 1105 in year one who were not exposed to the technology of the TI-Navigator™ system as the

CCT for instruction. The year two group consisted of students in year two who were taught with the TI-Navigator^{TM} system as CCT. The *t*-test for independent means was used to test if there were differences in means of course grades and in student scores on the departmental final exams in each course for both groups. There was no significant different found in the final grades for students in both MAT 1033 and MAC 1105; however, there was a significant difference in the final exam scores at the $\alpha = .01$ level for both classes. In chapter 5, this study's findings and interpretations, recommendations, suggestions for further research, and conclusions will be discussed.

CHAPTER 5
DISCUSSION

Introduction

The purpose of this study was to examine whether classroom connectivity-based mathematics instruction would make a difference in student achievement in a two-year college mathematics classroom. College Algebra (MAC 1105) is a gatekeeper course and is one of the two general education mathematics courses needed for completion of a degree at a two-year college. Intermediate Algebra (MAT 1033) is the prerequisite course for College Algebra and is the entry point for most students in Florida given Senate Bill 1720. Finding an instructional strategy to help students be successful in these two courses is essential to their graduation from a two-year college or even continuation in the four-year university system. The study questioned whether the use of the TI-Navigator™ system as a CCT instructional tool would make a difference in student scores on the departmental final exams as well as course grades. The research questions the researcher wanted to answer were as follows:

RQ1: Is there a significant difference in student scores on the Intermediate Algebra departmental final exam from year one to year two when the CCT was used as an instructional strategy?

RQ2: Is there a significant difference in student grades in Intermediate Algebra from year one to year two when the CCT was used as an instructional strategy?

RQ3 Is there a significant difference in student scores on the College Algebra departmental final exam from year one to year two when the CCT was used as an instructional strategy?

RQ4: Is there a significant difference in student grades in College Algebra from year one to year two when the CCT was used as an instructional strategy?

This chapter will discuss the findings and interpretations of the study, recommendations for educations, and suggestions for further research.

Findings and Interpretations

There were four research questions listed above that were turned into hypotheses.

Results from Research Question 1

The first research question contemplates whether using CCT as an instructional method in MAT 1033 would make a difference in departmental final exam scores. The question was turned into the following null and alternative hypotheses:

$H1_0$: There is no significant difference in the mean student scores on the MAT 1033 departmental final exam from year one without CCT to year two with CCT as an instructional strategy.

$$H1_0:\ \mu_1 - \mu_2 = 0$$

$H1_a$: There is a significant difference in the mean student scores on the MAT 1033 departmental final exam from year one without CCT to year two with CCT as an instructional strategy.

$$H1_a:\ \mu_1 - \mu_2 \neq 0$$

The departmental final exam for MAT 1033 (see Appendix A) was given to each participant at the end of each semester. The multiple choice test used scantron sheets for student answers. After being scanned, the data was then inputted in a spreadsheet for data analysis in IBM SPSS Statistics 23. A *t*-test for independent means was performed resulting in a $t = -2.823$ and a p-value = .005. There is a statistically significant difference in the mean exam scores from year one to year two at the $\alpha = .01$ level. In fact, this difference was in favor of using CCT as an instructional strategy to improve student scores on mathematics exams. The 99% confidence interval shows that when instructors use CCT as an instructional tool, we can expect to see student scores when instructors use CCT to be about a half of a percentage point to 10 percentage points greater than scores from those students who were instructed without CCT.

The Cohen's *d* effect size was calculated to be *d* = .32. This effect size would indicate the treatment had a small effect on the mean scores of the departmental final exam.

Results from Research Question 2

The second research question contemplates whether using CCT as an instructional method in MAT 1033 would improve students' course grades. The question was turned into the following null and alternative hypotheses:

$H2_0$: There is no significant difference in the mean MAT 1033 course grades from year one without CCT to year two with CCT as an instructional strategy.

$$H2_0: \mu_1 - \mu_2 = 0$$

$H2_a$: There is a significant difference in the mean MAT 1033 course grades from year one without CCT to year two with CCT as an instructional strategy.

$$H2_a: \mu_1 - \mu_2 \neq 0$$

Grades were collected from the college's registrar's office. They were imported into a Microsoft Excel file and coded by the researcher for data analysis in IBM SPSS Statistics 23. The researcher used a coding scheme equivalent to the college's grade point average (GPA) system. A *t*-test for difference in means of course grades was tested. The test revealed a $t = -1.15$ and a p-value = .251 meaning no statistical difference. Thus, the use of CCT did not significantly impact students' course grades.

Results from Research Question 3

The third research question contemplates whether using CCT as an instructional method in MAC 1105 would make a difference in departmental final exam scores. The question was turned into the following null and alternative hypotheses:

$H3_0$: There is no significant difference in the mean student scores on the MAC 1105 departmental final exam from year one without CCT to year two with CCT as an instructional strategy.

$$H3_0\colon\ \mu_1 - \mu_2 = 0$$

H3a: There is a significant difference in the mean student scores on the MAC 1105 departmental final exam from year one without CCT to year two with CCT as an instructional strategy.

$$H3_a\colon\ \mu_1 - \mu_2 \neq 0$$

The departmental final exam for MAC 1105 (see Appendices B and C) was given to each participant at the end of each semester. The multiple choice test used scantron sheets for student answers. After being scanned, the data was then inputted in a spreadsheet for data analysis in IBM SPSS Statistics 23. A t-test for independent means was performed resulting in a t = -3.624 and a p-value = .000. There is a statistically significant difference in the mean exam scores from year one to year two at the α = .01 level. In fact, this difference was in favor of using CCT as an instructional strategy to improve student scores on mathematics exams. The 99% confidence interval shows we can expect to see student scores when instructors use CCT to be approximately one and a half of a percentage point to 10 percentage points greater than scores from those students who were instructed without CCT.

The Cohen's d effect size was calculated to be d = .42. This effect size would indicate the treatment had a moderate effect on the mean scores of the departmental final exam.

Results from Research Question 4

The fourth research question contemplates whether using CCT as an instructional method in MAC 1105 would make a student course grades. The question was turned into the following null and alternative hypotheses:

H4₀: There is no significant difference in the mean MAC 1105 course grades from year one without CCT to year two with CCT as an instructional strategy.

$$H4_0\colon \mu_1 - \mu_2 = 0$$

H4$_a$: There a significant difference in the mean MAC 1105 course grades from year one without CCT to year two with CCT as an instructional strategy.

$$H4_a: \mu_1 - \mu_2 \neq 0$$

Grades were collected from the college's registrar's office. They were imported into a Microsoft Excel file and coded by the researcher for data analysis in IBM SPSS Statistics 23. The researcher used a coding scheme equivalent to the college's grade point average (GPA) system. A *t*-test for difference in means of course grades was tested. The test revealed a $t = 0.237$ and a p-value = .813, meaning no statistical difference. As in the case of MAT 1033, using CCT did not significantly impact MAC 1105 students' course grades.

Summary of Findings

These findings were similar for both courses and is very important to stress. In both MAT 1033 and MAC 1105, the teacher use of discourse coupled with the TI-Navigator^{TM} system as an instructional tool had positive effects on student achievement on their common departmental final exams. Both courses saw as much as a 10-point increase in student scores. Also keep in mind, graphing calculators were not allowed for these common departmental final exams, and students were only allowed scientific calculators for these exams. The use of the graphing calculators with the TI-Navigator^{TM} system was strictly for instructional use only. This has significant implications for two-year colleges nationwide wanting to improve student achievement on examinations.

Recommendations

Technology has become a common part of everyday life and is beneficial in many ways. Not only is technology valuable in daily tasks such as navigation, communication, and information technology, to name a few, but it also improves learning. Research has shown technology can increase student achievement in mathematics at the elementary (Dix, 2013), intermediate (Jacobs, 2013), secondary (Camara, 2013; Irving, et al., 2010; Lyublinskaya & Tournaki, 2011), and collegiate levels (Caldwell, 2007; Ellington, 2006; Pankow, 1994; Quesada & Maxwell, 1994; Reznichenko, 2012). The results from this study have supported those studies for student achievement, and, in addition, show that the TI-Navigator™ system can improve student scores on mathematics exams when used as an instructional tool in the two-year college mathematics classroom. This indicates introducing CCT into the mathematics classroom can be an important instructional tool at two-year colleges. Even though course grades were not improved, this could be attributed to instructor subjective grading with other assignments making up the final course grade and does not necessarily correlate to student learning. For instance, some instructors, but not all, use attendance as part of their final grades which does not measure student learning. Student learning was shown to improve through the final exam grades when instructors used CCT in their mathematics classroom.

The finding from this study falls in line with improvement of scores and performance on tests at the secondary level (Dougherty & Hobbs, 2007; Owens el al., 2008), improvements in student achievement at the secondary level (Irving et al., 2008), but not in student achievement at the collegiate level (Powers & Champion, 2008). This study also extends them by focusing on the two-year college mathematics student. This model could be used by any two-year educational institution seeking improvement in mathematics instruction, but needs further results in causality.

If institutions would like to implement this strategy, they should do so systematically and logically with faculty and administrative support. The importance of faculty buy-in is immense because if instructors do not believe in it, it will never work. Instructors have control over attitudes in the classroom. If an instructor shows their disinterest in the CCT, students will become disinterested. Instructors could also choose just not to use it in their classroom.

It is also essential that administration be fully supportive of faculty and supportive in the process of getting faculty the professional development for proper implementation in the classroom. The institution must be willing to take on the initial and continued financial burden of this equipment and professional development. This two-year college sought additional funding through grants to help offset the cost of the TI-Navigator™ system equipment and professional development training. They also sought out partnerships with Texas Instruments and university faculty to facilitate training. Efforts such as these help alleviate some of the costs any institution would incur. Ultimately, the goal of this study was to show improvements in student achievement when CCT was implemented in the two-year college mathematics classroom as an instructional tool. Most likely any institution's goal would include to improve student achievement in mathematics. Even though student course grades did not improve, student learning improved through gains in mean scores on the departmental final exams.

The increase in students' departmental final exam scores from year one to year two when CCT was used for instructional purposes suggests that two-year college mathematics students could benefit from the technology. The results showed a 10% increase in student exam scores when CCT was employed over just one year of the study in courses taught by mostly stable faculty population to a homogenous group of students, even though the make-up of the student groups changed from year one to year two. This increase was statistically significant. This researcher questions whether the overall impact would increase more over a longer length of time for faculty to become more comfortable and familiar with the use of CCT in class. Local, state, and national educational organizations should lobby for more funding to allow for colleges and schools to explore more CCT-based instruction in critical mathematics courses like the ones in this study.

Suggestions for Further Research

Further research that was not addressed in this study should be performed in the two-year college mathematics classrooms involving the TI-Navigator™ system. The following are suggestions for further research:

1. Research should replicate this study in an urban two-year college with a heterogeneous population of students.
2. Research should expand to include a line item analysis of exam items. Does CCT benefit certain question types in mathematics over other types?
3. Research should include differences in benefit based on ethnicity. This study's sample size did not allow for this type of study. Does CCT benefit some ethnicities over others?
4. Research should include differences in benefit based on age of the student. This study's sample size did not allow for this type of study. Does CCT benefit some age groups over others?
5. Research should look at the difference in gender. Does CCT benefit a certain gender over the other?
6. Research should be extended over a longer period of time. Does the benefit of CCT in the mathematics classroom increase over time?
7. For course grades, research should include instructors teaching a section without CCT and a class with CCT to see if there are difference in course grades.

8. Research should also include the level of use by instructor. Is there a relationship between the level of use by the instructor and student achievement?

9. Research should include a true experimental setting that would involve a random assignment to control groups and experimental groups.

10. Research should include a pretest—posttest given to the experimental as well as a control group at several two-year colleges to investigate a generalization of results.

11. Research should investigate factors for causality.

12. Research should include how instructor beliefs about CCT would effect their use of the technology, and whether, as a consequence, this impacts student learning in mathematics at a two-year college.

13. Research should include whether instructor demographics have an impact on their use of the technology at a two-year college.

14. Finally, research should include whether instructor demographics have an impact on student learning in mathematics at two-year college.

Conclusion

In this study, it was initially thought that there would be a significant difference in both course grades and departmental final exam grades for students from year one students that were taught without CCT-based instruction to year two students who were introduced to CCT as the form of instruction. The assumption was that year two students would outperform year one students given this base of instruction. However, we did not find any significant difference in course grades. This could have been due to instructor differences in subjectivity of issuing grades. Conversely, a significant difference in departmental final exam scores was found for both MAT 1033 and MAC 1105 with an effect size of $d = .32$ and $d = .42$, respectively, showing student learning improves in mathematics when CCT is employed as an instructional tool in the classroom. These findings can have major implications for two-year college mathematics departments wanting to improve student scores on their examinations.

With legislation allowing students to enter college-level mathematics coursework in some states without proper placement into these classes, two-year colleges have to be more creative in how they prepare students for college-level mathematics.

APPENDIX A

DEPARTMENTAL FINAL EXAM FOR MAT 1033 FOR THE 2009-2010 AND 2010-2011 SCHOOL YEARS

MAT 1033 [redacted]

Final Exam – Part 1

FORM D

PLEASE DO NOT WRITE ON THIS PART OF THE EXAM!

MULTIPLE CHOICE. Choose the best response and bubble in the the answer on your Scantron answer form provided. Be sure to put your test version on the Scantron form.

Find the indicated function value.

1) Find f(−5) when $f(x) = \frac{x^2 - 8}{x^3 + 6x}$.

A) $-\frac{1}{7}$ B) $-\frac{17}{125}$ C) $-\frac{17}{155}$ D) $-\frac{5}{31}$

Determine whether the equation is an identity, a conditional equation, or an inconsistent equation.

2) $18x + 8(x + 1) = 26(x + 1) - 18$

A) Conditional equation B) Identity C) Inconsistent equation

Solve.

3) A car rental agency charges \$225 per week plus \$0.20 per mile to rent a car. The total cost, C, for the renting the car for one week and driving it x miles can be modeled by the formula $C = 0.20x + 225$. How many miles can you travel in one week for \$245?

A) 100 miles B) 1225 miles C) 75 miles D) 274 miles

Find the domain and range.

4) {(41, −2), (5, −1), (5, 0), (6, 1), (14, 3)}

A) domain: {41, 6, 5, 14}; range: {−2, −1, 0, 1, 3}

B) domain: {−2, −1, 0, 1, 3}; range: {41, 6, 5, 14}

C) domain: {−2, −1, 1, 3}; range: {41, 6, 5, 14}

D) domain: {41, 6, 5, 14}; range: {−2, −1, 1, 3}

Decide whether the relation is a function.

5) {(−6, −6), (2, −9), (4, −7), (3, 4), (9, −6)}

A) function B) not a function

Find the indicated function value.

6) $f(x) = 2x + 4$, $g(x) = 2x^2 + 1$

Find (f + g)(2).

A) 17 B) 15 C) 13 D) 11

Find the solution set for the equation.

7) $|6x + 9| + 4 = 11$

A) $\left\{-\frac{2}{9}, -\frac{16}{9}\right\}$ B) ∅ C) $\left\{-\frac{1}{3}\right\}$ D) $\left\{-\frac{1}{3}, -\frac{8}{3}\right\}$

p. 1 – D – 2009

Figure A-1. Page 1 of the departmental final exam for MAT 1033.

Solve the inequality. Graph the solution set on a number line.

8) $-6(6x - 2) < -42x - 18$

A) $[1, \infty)$

B) $[1, \infty)$

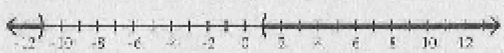
C) $(-\infty, 1]$

D) $(-\infty, 1)$

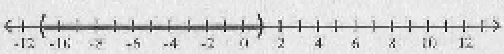
Solve and graph the solution set on a number line.

9) $|x + 5| < 6$

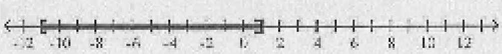
A) $(-\infty, -11) \cup (1, \infty)$



B) $(-11, 1)$



C) $[-11, 1]$



D) $\varnothing$

Find the slope of the line that goes through the given points.

10) (2, 14), (10, 1)

A) $-\frac{8}{13}$ B) $-\frac{13}{8}$ C) $\frac{13}{8}$ D) $\frac{5}{4}$

Find the slope.

11) Find the slope of a line parallel to the line $-9x - 8y = -5$.

A) -5 B) $\frac{8}{9}$ C) $-\frac{9}{8}$ D) undefined

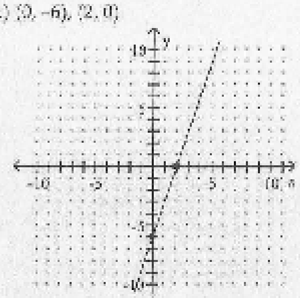
p. 2 - D - 2009

Figure A-2. Page 2 of the departmental final exam for MAT 1033.

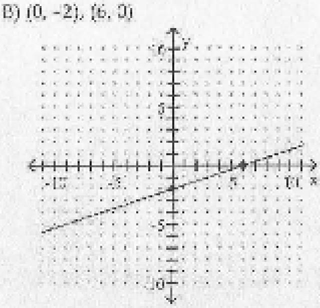
Determine the intercepts and use them to graph the linear function.

12) $5x - 15y = 30$

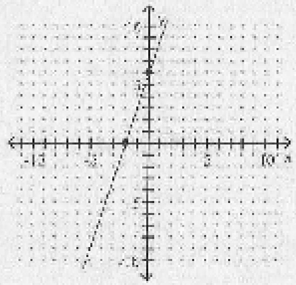
A) (0, −6), (2, 0)



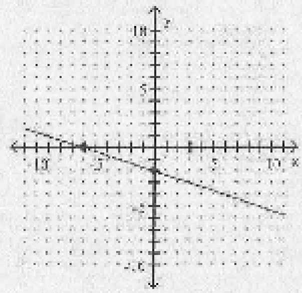
B) (0, −2), (6, 0)



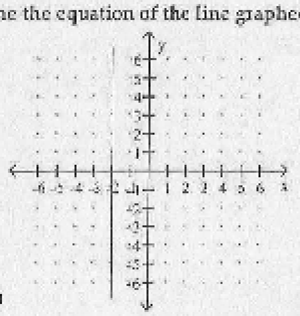
C) (0, 6), (−2, 0)



D) (0, −2), (−6, 0)



Determine the equation of the line graphed below.



13)

A) $y = -2$ B) $x - y = -2$ C) $x = -2$ D) $y = x - 2$

Write the equation of the line with given conditions using function notation.

14) Slope $= -\frac{2}{7}$, passing through (0, 2)

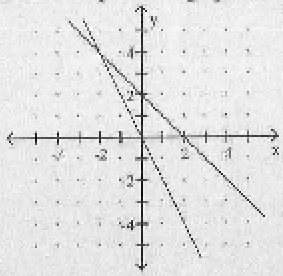
A) $y - 2 = -\frac{2}{7}(x - 0)$ B) $f(x) = -\frac{2}{7}x + 2$ C) $7x + 9y = 36$ D) $f(x) = \frac{2}{7}x - 2$

p. 3 - D - 2009

Figure A-3. Page 3 of the departmental final exam for MAT 1033.

A system of linear equation is graphed below. Look at the graph and determine the solution.

15)



A) (0, 0) and (2, 0) B) (4, -2) C) (-2, 4) D) ∅

Use the substitution method to determine if the system has one solution, is dependent, or is inconsistent

16) $y = -7x + 6$
$-35x - 5y = -40$

A) one solution B) inconsistent C) dependent

Solve the system by the addition method.

17) $2x + y = 8$
$8x - 4y = 32$

A) {(5, -2)} B) ∅ C) {(0, 8)} D) $\{(x, y) \mid 2x + y = 8\}$

Use factoring to solve the quadratic equation.

18) $8x^2 + 18x - 9 = 0$

A) $\left\{\frac{3}{2}, \frac{3}{4}\right\}$ B) $\left\{-\frac{3}{2}, -\frac{3}{4}\right\}$ C) $\left\{\frac{3}{2}, -\frac{3}{4}\right\}$ D) $\left\{-\frac{3}{8}, -\frac{1}{3}\right\}$

Solve the equation by the square root property. If possible, simplify radicals or rationalize denominators. Express imaginary solutions in the form a + bi.

19) $(x - 11)^2 = -144$

A) $\{11 \pm 12i\}$ B) $\{-11 \pm 12i\}$ C) $\{11 \pm 12\}$ D) $\left\{\pm\frac{12i}{11}\right\}$

Use the quadratic formula to solve the equation.

20) $5x^2 + 8x + 2 = 0$

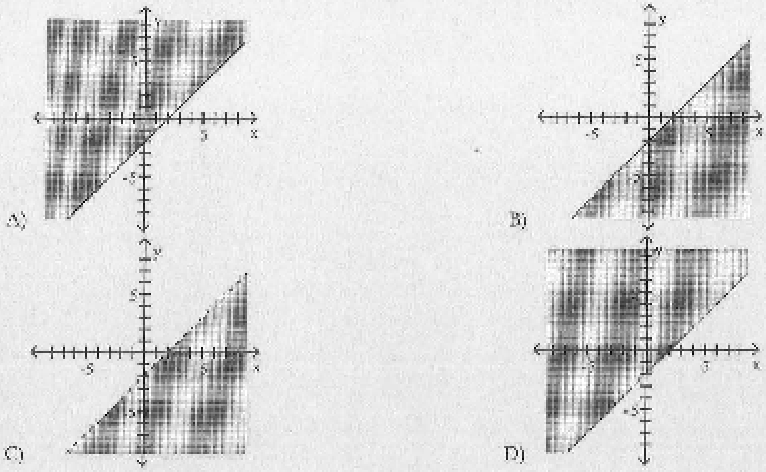
A) $\left\{\frac{-8 \pm \sqrt{6}}{5}\right\}$ B) $\left\{\frac{-4 \pm \sqrt{26}}{3}\right\}$ C) $\left\{\frac{-4 \pm \sqrt{6}}{5}\right\}$ D) $\left\{\frac{-4 \pm \sqrt{6}}{10}\right\}$

p. 4 - D - 2009

Figure A-4. Page 4 of the departmental final exam for MAT 1033.

Graph the inequality.

21) $y \geq x - 2$



Divide as indicated.

22) $\dfrac{5x - 5}{x} \div \dfrac{10x - 10}{5x^2}$

A) $\dfrac{50x^2 + 100x + 50}{5x^3}$ B) $\dfrac{5x}{2}$ C) $\dfrac{25x^3 - 25x^2}{10x^2 - 10x}$ D) $\dfrac{2}{5x}$

Solve the rational equation.

23) $\dfrac{5 - a}{a} + \dfrac{3}{4} = \dfrac{7}{a}$

A) $\{-8\}$ B) $\{-4\}$ C) $\left\{\sqrt{\dfrac{29}{20}}\right\}$ D) $\{8\}$

Multiply and simplify. Assume that all variables in a radicand represent positive real numbers.

24) $\sqrt{6xy} \cdot \sqrt{3xy^2}$

A) $3x^2y^2\sqrt{2y}$ B) $3xy\sqrt{2y}$ C) $xy\sqrt{18y}$ D) $3xy^2\sqrt{2}$

Find the indicated root, or state that the expression is not a real number.

25) $\sqrt[3]{-27ab^4}$

A) $-3b\sqrt[3]{a}$ B) $3b\sqrt[3]{ab}$ C) $-3b\sqrt[3]{ab}$ D) Not a real number

Solve the equation.

26) $\sqrt{3x - 8} = 5$

A) $\{11\}$ B) $\{-1\}$ C) $\left\{\dfrac{13}{3}\right\}$ D) $\left\{\dfrac{17}{3}\right\}$

p. 5- D - 2009

Figure A-5. Page 5 of the departmental final exam for MAT 1033.

APPENDIX B
DEPARTMENTAL FINAL EXAM FOR MAC 1105 IN 2009-2010 SCHOOL YEAR

MAC 1105-College Algebra Final Exam-Multiple Choice Section FORM A

[redacted]

Instructions: Please answer all problems by filling in the appropriate bubbles on the SCANTRON sheet. Place all scratch work on the scratch paper provided. PLEASE DO NOT WRITE ON THE TEST.

Solve the absolute value equation or indicate that the equation has no solution.

1) $|2x + 9| + 5 = 9$

A) $\left\{\frac{5}{2}, \frac{13}{2}\right\}$ B) $\left\{-\frac{13}{2}, -\frac{5}{2}\right\}$ C) $\left\{-\frac{13}{9}, -\frac{5}{9}\right\}$ D) $\emptyset$

Solve the equation.

2) $\frac{16}{8x - 8} + \frac{1}{8} = \frac{2}{x - 1}$

A) $\{1, 8\}$ B) $\{1\}$ C) $\emptyset$ D) $\{-1\}$

Solve the equation.

3) $3(x - 5)^2 = 9$

A) $\{-5 + \sqrt{3}\}$ B) $\{-8, -2\}$ C) $\{2, 8\}$ D) $\{5 \pm \sqrt{3}\}$

Solve the radical equation.

4) $x - \sqrt{3x - 2} = 4$

A) $\{-1\}$ B) $\{2, 9\}$ C) $\{9\}$ D) $\{1, 2\}$

In solving the following equation by completing the square, what will the equation look like when the square is completed?

5) $x^2 - 12x - 7 = 0$

A) $(x + 6)^2 = 43$ B) $(x - 6)^2 = 29$ C) $(x - 6)^2 = 43$ D) $(x - 36)^2 = 43$

Solve the equation.

6) $x^4 - 7x^2 - 18 = 0$

A) $\{-9, 2\}$ B) $\{-3, 3, -i\sqrt{2}, i\sqrt{2}\}$ C) $\{3, i\sqrt{2}\}$ D) $\{-\sqrt{2}, \sqrt{2}, -3i, 3i\}$

Solve the polynomial function.

7) $x^3 - 2x^2 - 9x + 18 = 0$

A) $x = 2, x = 9$ B) $x = -2, x = -3, x = 3$
C) $x = 2, x = -3, x = 3$ D) $x = -3, x = 3$

Solve the equation using the quadratic formula.

8) $x^2 + 10x + 41 = 0$

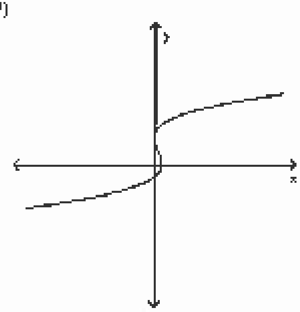
A) $\{-5 + 4i\}$ B) $\{-9, -1\}$ C) $\{-5 - 4i, -5 + 4i\}$ D) $\{-5 - 16i, -5 + 16i\}$

1

Figure B-1. Page 1 of the departmental final exam for MAC 1105 for 2009-2010.

Determine whether or not the graph represents a function.

9)

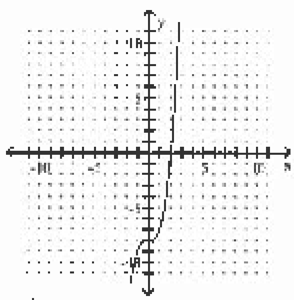


A) not a function

B) function

Identify the intercepts.

10)



A) (2, 0), (0, −8)

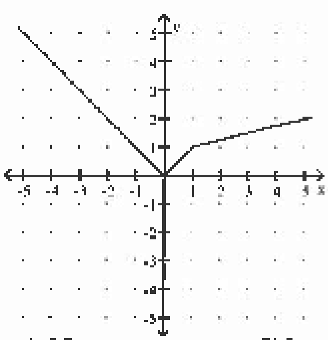
B) (2, 2), (−8, −8)

C) (2, 0), (0, 8)

D) (−2, 0), (0, −8)

Use the graph to find the indicated function value.

11) y = f(x). Find f(−3)



A) 1.5

B) 9

C) −5

D) 3

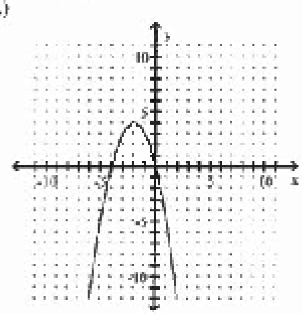
2

Figure B-2. Page 2 of the departmental final exam for MAC 1105 for 2009-2010.

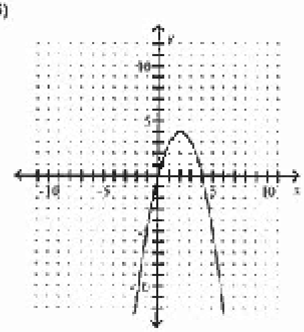
Use the vertex and intercepts to sketch the graph of the quadratic function.

12) $f(x) = 4 - (x - 2)^2$

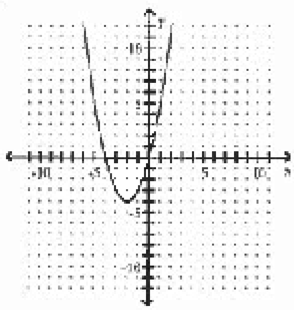
A)



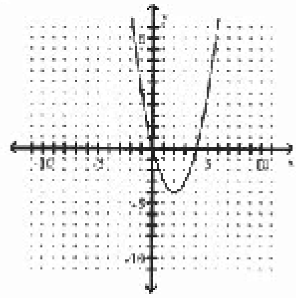
B)



C)



D)



Find the vertical asymptotes, if any, of the graph of the rational function.

13) $h(x) = \dfrac{x + 4}{x^2 - 16}$

A) $x = 4$
B) $x = 4, x = -4$
C) $x = -4$
D) no vertical asymptote

Find the horizontal asymptote, if any, of the given function.

14) $g(x) = \dfrac{20x^2}{5x^2 + 1}$

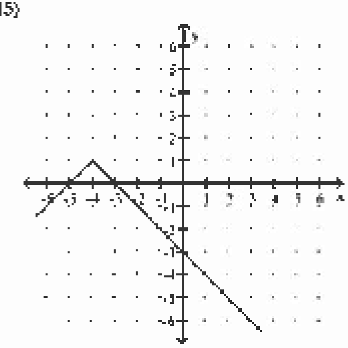
A) $y = \dfrac{1}{4}$
B) $y = 4$
C) $y = 0$
D) no horizontal asymptote

3

Figure B-3. Page 3 of the departmental final exam for MAC 1105 for 2009-2010.

Use the graph to determine the function's domain and range.

15)



A) domain: $(-\infty, \infty)$
range: $(-\infty, \infty)$

B) domain: $(-\infty, -4]$
range: $(-\infty, 1]$

C) domain: $(-\infty, \infty)$
range: $(-\infty, 1]$

D) domain: $(-\infty, -4)$ or $(-4, \infty)$
range: $(-\infty, 1)$ or $(1, \infty)$

Solve the polynomial inequality and graph the solution set on a number line. Express the solution set in interval notation.

16) $x^2 - 2x \le 3$

A) $(-\infty, -3] \cup [1, \infty)$

B) $[-1, 3]$

C) $[-3, 1]$

D) $(-3, 1)$

Given functions f and g, perform the indicated operations.

17) $f(x) = 6x - 2, \quad g(x) = 4x - 5$
Find fg.

A) $10x^2 - 36x - 7$ B) $24x^2 - 13x + 10$ C) $24x^2 - 38x + 10$ D) $24x^2 + 10$

For the given functions f and g, find the indicated composition.

18) $f(x) = 7x + 8, \quad g(x) = 3x - 1$
$(f \circ g)(x)$

A) $21x + 23$ B) $21x + 1$ C) $21x + 15$ D) $21x + 7$

4

Figure B-4. Page 4 of the departmental final exam for MAC 1105 for 2009-2010.

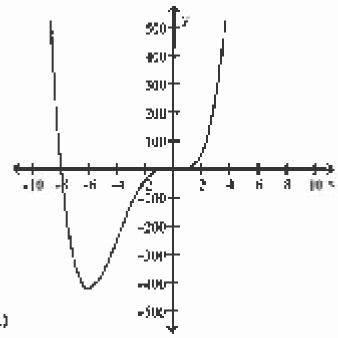
Solve the logarithmic equation.

19) $\log_2 x + \log_2 (x - 3) = 2$

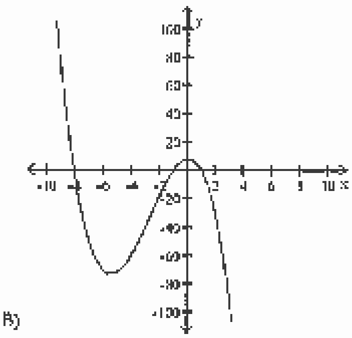
A) {4}   B) {-1, 4}   C) {1, -4}   D) {2}

Graph the polynomial function.

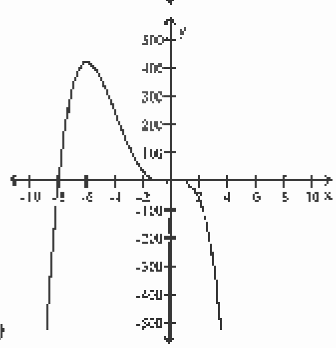
20) $f(x) = x^3 + 8x^2 - x - 8$



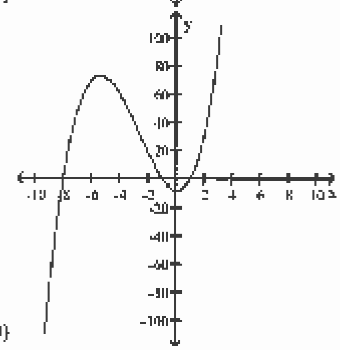
A)



B)



C)



D)

Find the domain of the function.

21) $f(x) = \sqrt{8 - x}$

A) $(-\infty, 2\sqrt{2}) \cup (2\sqrt{2}, \infty)$

B) $(-\infty, 8) \cup (8, \infty)$

C) $(-\infty, 8]$

D) $(-\infty, 2\sqrt{2}]$

Solve the equation.

22) $4^{(1 + 2x)} = 1024$

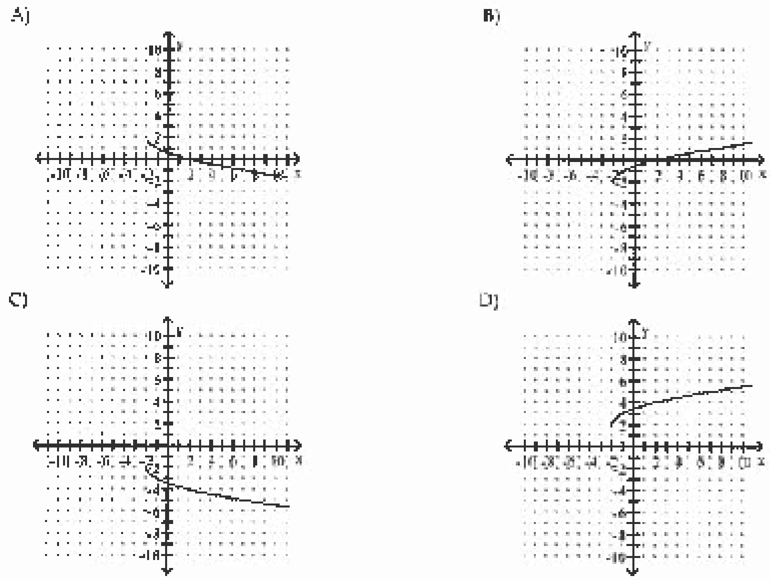
A) {-2}   B) {2}   C) {8}   D) {256}

5

Figure B-5. Page 5 of the departmental final exam for MAC 1105 for 2009-2010.

Graph the given function.

23) $g(x) = -\sqrt{x + 2} - 2$



Solve the system. Identify systems with no solution and systems with infinitely many solutions, using set notation to express their solution sets.

24) $x - 5y = 3$
$2x - 10y = 6$

A) $\{(3, 0)\}$ B) $\{(0, 0)\}$ C) $\{(x, y) \mid x - 5y = 3\}$ D) $\emptyset$

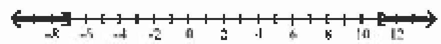
6

Figure B-6. Page 6 of the departmental final exam for MAC 1105 for 2009-2010.

Solve the absolute value inequality. Other than ∅, use interval notation to express the solution set and graph the solution set on a number line.

25) $|x - 2| - 7 \le 2$

A) $(-\infty, -7] \cup [11, \infty)$



B) $(-7, 11)$

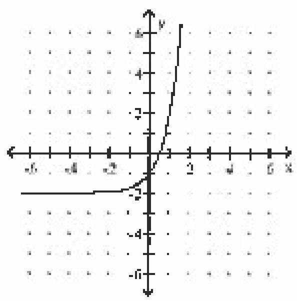
C) $[-7, 2]$

D) $[-7, 11]$

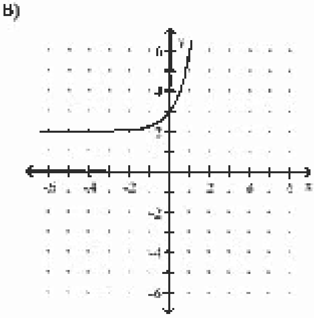
Graph the function.

26) $g(x) = 4^x - 2$.

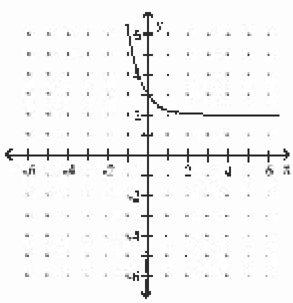
A)



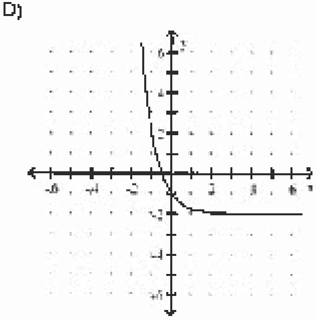
B)



C)



D)

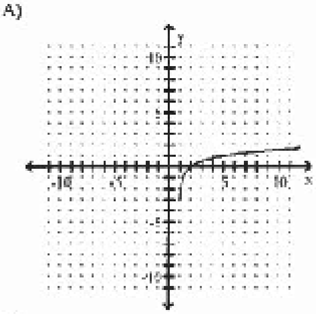


7

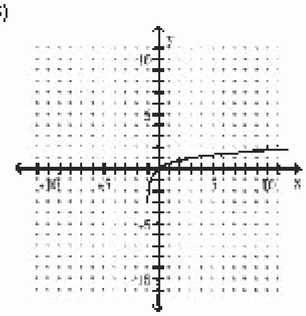
Figure B-7. Page 7 of the departmental final exam for MAC 1105 for 2009-2010.

27) Use the graph of $\log_4 x$ to obtain the graph of $f(x) = \log_4 (x + 1)$.

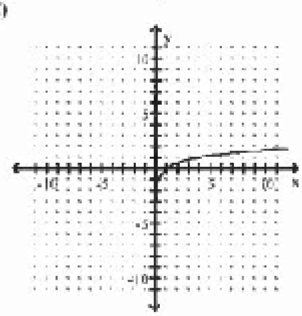
A)



B)



C)



D)

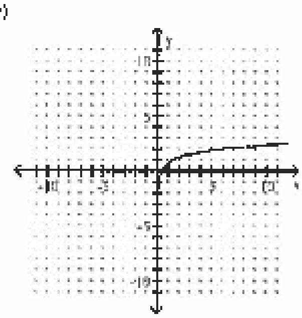


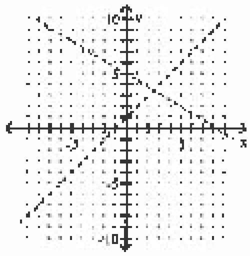
Figure B-8. Page 8 of the departmental final exam for MAC 1105 for 2009-2010.

Graph the solution set of the system of inequalities or indicate that the system has no solution.

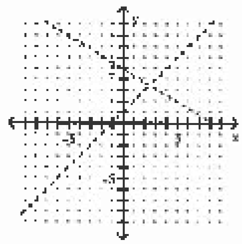
28) $y < x + 1$

$3x + 5y > 25$

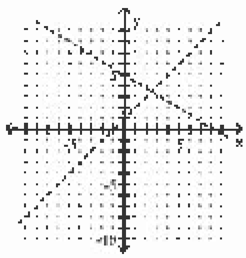
A)



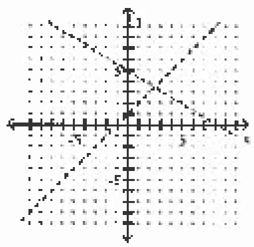
B)



C)



D)



Solve.

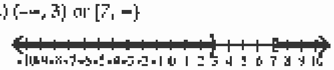
29) The value of a particular investment follows a pattern of exponential growth. In the year 2000, you invested money in a money market account. The value of your investment t years after 2000 is given by the exponential growth model $A = 2600e^{0.045t}$. When will the account be worth $3898?

A) 2009 B) 2010 C) 2008 D) 2011

Solve the rational inequality and graph the solution set on a real number line. Express the solution set in interval notation.

30) $\frac{-x + 7}{x - 3} \geq 0$

A) $(-\infty, 3)$ or $[7, \infty)$



B) $(-\infty, 7]$

C) $[3, 7]$

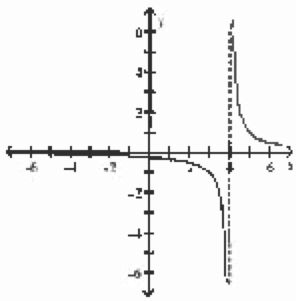
D) $(3, 7]$

Figure B-9. Page 9 of the departmental final exam for MAC 1105 for 2009-2010.

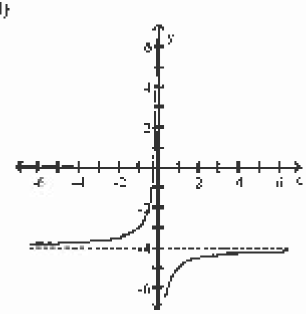
Use transformations of $f(x) = \frac{1}{x}$ to graph the rational function.

31) $f(x) = \frac{1}{x} - 4$

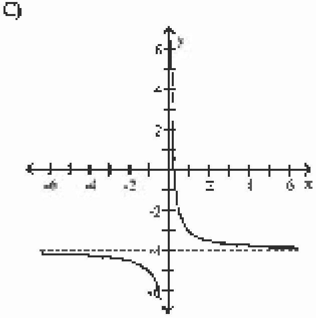
A)



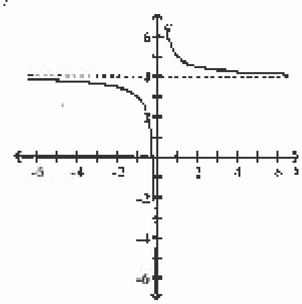
B)



C)



D)



10

Figure B-10. Page 10 of the departmental final exam for MAC 1105 for 2009-2010.

APPENDIX C
DEPARTMENTAL FINAL EXAM FOR MAC 1105 IN 2010-2011 SCHOOL YEAR

Multiple Choice Section

Instructions: Please answer all problems by filling in the appropriate bubbles on the SCANTRON sheet. Place all scratch work on the scratch paper provided.

Solve the absolute value equation or indicate that the equation has no solution.

1) $|4x + 6| + 9 = 13$

A) $\left\{-\frac{5}{2}, -\frac{1}{2}\right\}$ B) $\left\{-\frac{5}{3}, -\frac{1}{3}\right\}$ C) $\left\{\frac{1}{2}, \frac{5}{2}\right\}$ D) $\varnothing$

Solve the equation.

2) $\frac{x}{2x+2} = \frac{-2x}{4x+4} + \frac{2x-3}{x+1}$

A) $\{3\}$ B) $\left\{\frac{3}{2}\right\}$ C) $\left\{-\frac{12}{5}\right\}$ D) $\{-3\}$

Solve the equation.

3) $(5x + 4)^2 = 10$

A) $\left\{\frac{4-\sqrt{10}}{5}, \frac{4+\sqrt{10}}{5}\right\}$ B) $\left\{\frac{-4-\sqrt{10}}{5}, \frac{-4+\sqrt{10}}{5}\right\}$

C) $\left\{-\frac{14}{5}, \frac{6}{5}\right\}$ D) $\left\{\frac{\sqrt{10}-4}{5}, \frac{\sqrt{10}+4}{5}\right\}$

Solve the radical equation.

4) $\sqrt{30x - 15} = x + 7$

A) $\{8\}$ B) $\{-7\}$ C) $\{6\}$ D) $\{-8\}$

In solving the following equation by completing the square, what will the equation look like when the square is completed?

5) $x^2 - 12x - 7 = 0$

A) $(x-6)^2 = 29$ B) $(x-36)^2 = 43$ C) $(x-6)^2 = 43$ D) $(x+6)^2 = 43$

Solve the equation.

6) $x^4 - 20x^2 + 64 = 0$

A) $\{2, 4\}$ B) $\{-2i, 2i, -4i, 4i\}$ C) $\{-2, 2, -4, 4\}$ D) $\{4, 16\}$

Solve the polynomial equation.

7) $x^3 + 6x^2 - x - 6 = 0$

A) $\{-1, 1, -6\}$ B) $\{-6, 6\}$ C) $\{1, -6, 6\}$ D) $\{36\}$

Solve the equation using the quadratic formula.

8) $x^2 - 8x + 20 = 0$

A) $\{4 + 2i, 4 - 2i\}$ B) $\{4 - 4i, 4 + 4i\}$ C) $\{6, 2\}$ D) $\{4 + 2i\}$

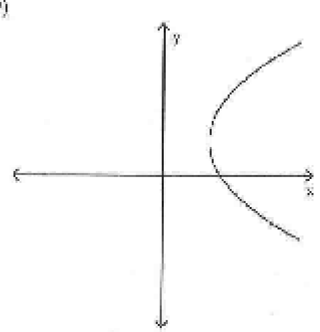
C-1 104

Figure C-1. Page 1 of the departmental final exam for MAC 1105 for 2010-2011.

[redacted]

Determine whether or not the graph is a graph in which y is a function of x.

9)

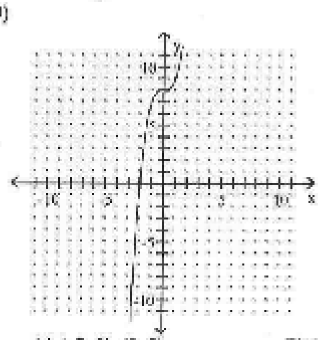


A) not a function

B) function

Identify the intercepts.

10)



A) (−2, 0), (0, 8)

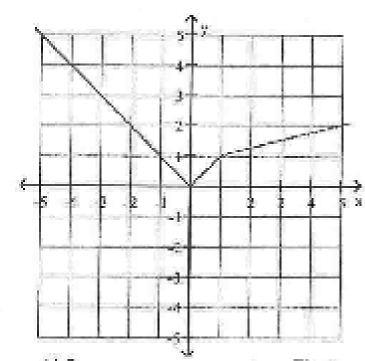
B) (−2, 0), (0, −8)

C) (2, 0), (0, 8)

D) (−2, −2), (8, 8)

Use the graph to find the indicated function value.

11) y = f(x). Find f(5).



A) 2

B) −5

C) 5

D) 17

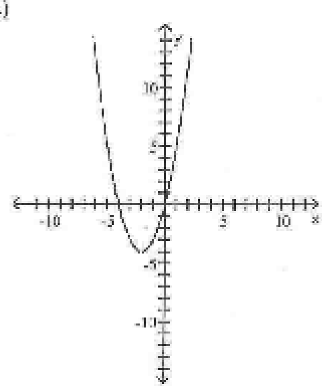
C-2

Figure C-2. Page 2 of the departmental final exam for MAC 1105 for 2010-2011.

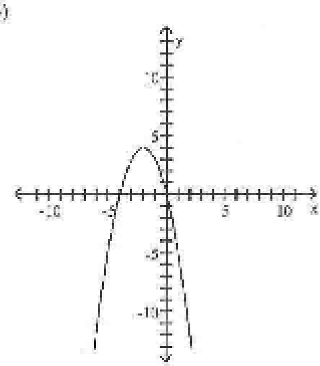
Use the information below to sketch the graph of the quadratic function.

12) A quadratic function with axis of symmetry $x = -2$ and a maximum value 4.

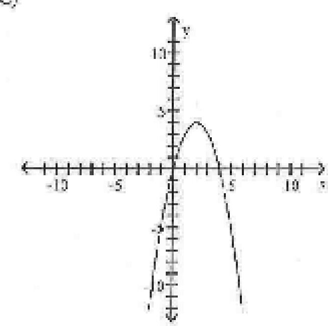
A)



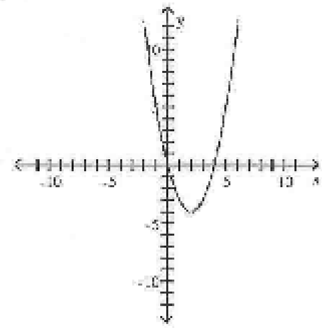
B)



C)



D)



Find the vertical asymptotes, if any, of the graph of the rational function.

13) $g(x) = \dfrac{x}{x^2 - 36}$

A) $x = 6$

B) $x = 6, x = -6$

C) $x = 6, x = -6, x = 0$

D) no vertical asymptote

Find the horizontal asymptote, if any, of the graph of the rational function.

14) $f(x) = \dfrac{10x}{5x^2 + 1}$

A) $y = 2$

B) $y = \dfrac{1}{2}$

C) $y = 0$

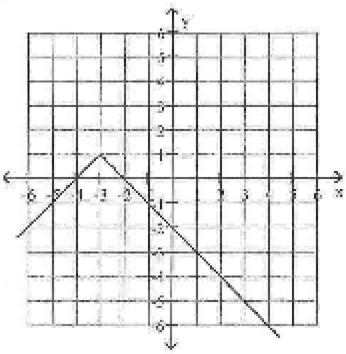
D) no horizontal asymptote

C-3

Figure C-3. Page 3 of the departmental final exam for MAC 1105 for 2010-2011.

Use the graph to determine the function's domain and range.

15)



A) domain: $(-\infty, -3)$ or $(-3, \infty)$
range: $(-\infty, 1)$ or $(1, \infty)$

B) domain: $(-\infty, -3]$
range: $(-\infty, 1]$

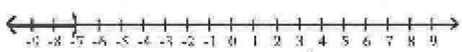
C) domain: $(-\infty, \infty)$
range: $(-\infty, 1]$

D) domain: $(-\infty, \infty)$
range: $(-\infty, \infty)$

Solve the polynomial inequality and graph the solution set on a number line. Express the solution set in interval notation.

16) $x^2 + 13x + 42 > 0$

A) $(-\infty, -7)$



B) $(-6, \infty)$

C) $(-\infty, -7) \cup (-6, \infty)$

D) $(-7, -6)$

Given functions f and g, perform the indicated operations.

17) $f(x) = 9x - 9$, $g(x) = 8x - 2$

Find fg.

A) $72x^2 + 18$ B) $72x^2 - 90x + 18$ C) $72x^2 - 74x + 18$ D) $17x^2 - 90x - 11$

For the given functions f and g, find the indicated composition.

18) $f(x) = 7x + 6$, $g(x) = 3x - 1$

$(f \circ g)(x)$

A) $21x + 17$ B) $21x + 5$ C) $21x + 13$ D) $21x - 1$

Figure C-4. Page 4 of the departmental final exam for MAC 1105 for 2010-2011.

Solve the logarithmic equation.

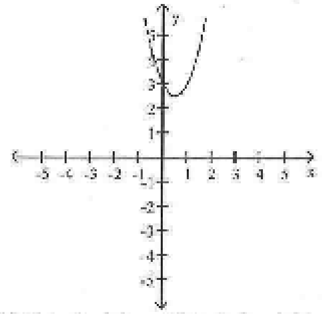
19) $\log_6 (x - 4) = 3$

A) {233} B) {220} C) {212} D) {725}

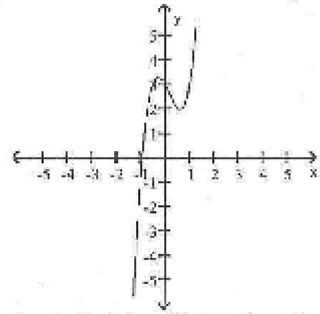
Use the Leading Coefficient Test to determine the end behavior of the polynomial function. Then use this end behavior to match the function with its graph.

20) f(x) is a polynomial function with degree 3 and leading coefficient $a = -4$.

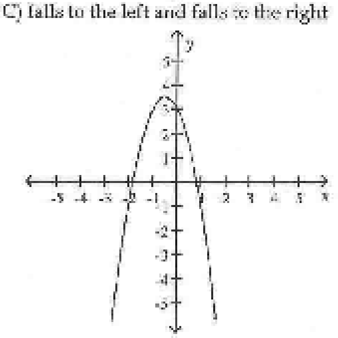
A) rises to the left and rises to the right



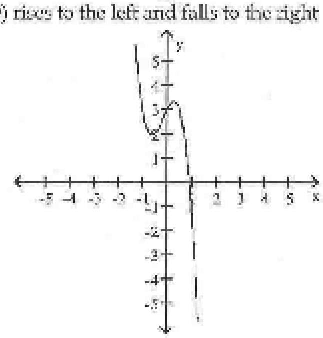
B) falls to the left and rises to the right



C) falls to the left and falls to the right



D) rises to the left and falls to the right



Find the domain of the function.

21) $y = \sqrt{6+x}$

A) $D = (-6, \infty)$ B) $D = (-\infty, -6]$ C) $D = (-\infty, -6)$ D) $D = [-6, \infty)$

Solve the equation by expressing each side as a power of the same base and then equating exponents.

22) $4^{(1 + 2x)} = 64$

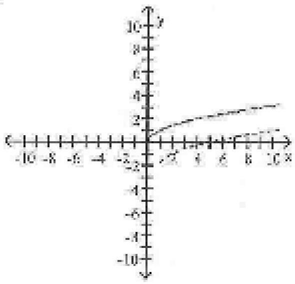
A) {4} B) {1} C) {−1} D) {16}

Figure C-5. Page 5 of the departmental final exam for MAC 1105 for 2010-2011.

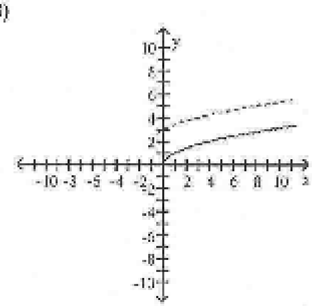
Begin by graphing the standard square root function $f(x) = \sqrt{x}$. Then use transformations of this graph to graph the given function.

23) $g(x) = f(x-1) + 2$

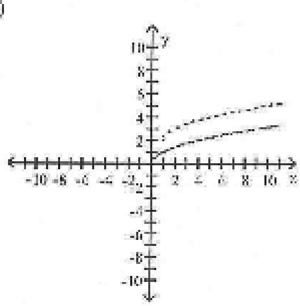
A)



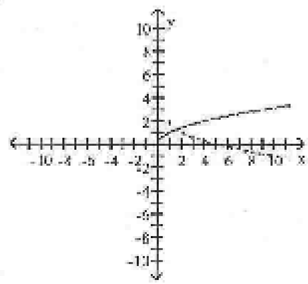
B)



C)



D)



Solve the system of equations.

24)
$$\begin{aligned} x - y + 4z &= -3 \\ 5x + z &= 0 \\ x + 2y + z &= 6 \end{aligned}$$

A) {(0, 3, 0)} B) {(3, 0, 0)} C) {(0, 0, 3)} D) {(0, 3, −3)}

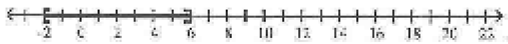
Figure C-6. Page 6 of the departmental final exam for MAC 1105 for 2010-2011.

Solve the absolute value inequality.

25) $|x - 2| < 4$

A) ∅

B) $[-2, 6]$



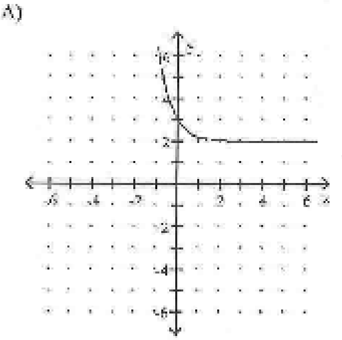
C) $(-\infty, -2) \cup (6, \infty)$

D) $(-2, 6)$

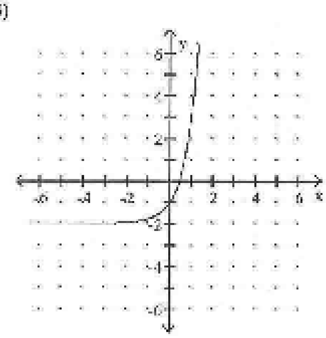
Graph the function.

26) Which graph best matches the exponential function $f(x) = a^x + 2$, where $a > 1$?

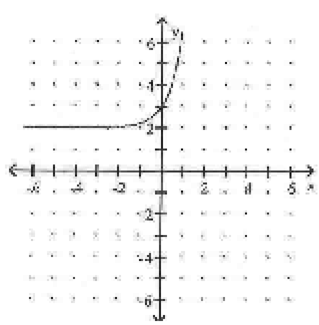
A)



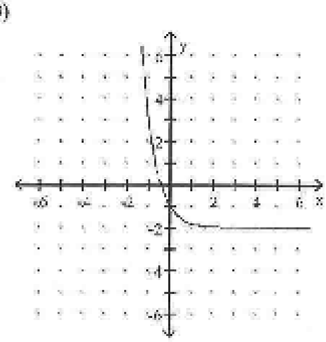
B)



C)



D)

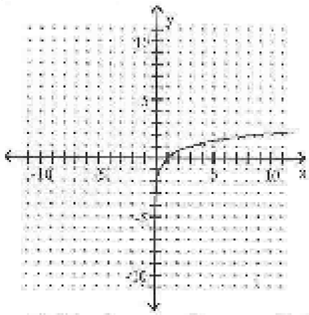


C-7

Figure C-7. Page 7 of the departmental final exam for MAC 1105 for 2010-2011.

The graph of a logarithmic function is given. Select the function for the graph from the options.

27)

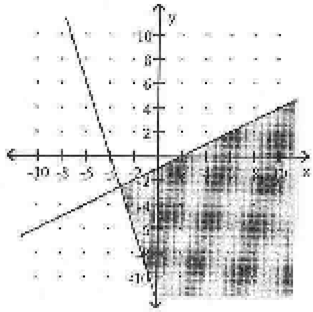


A) $f(x) = \log_3 (x + 1)$ B) $f(x) = \log_3 x$ C) $f(x) = \log_3 (x - 1)$ D) $f(x) = \log_3 x - 1$

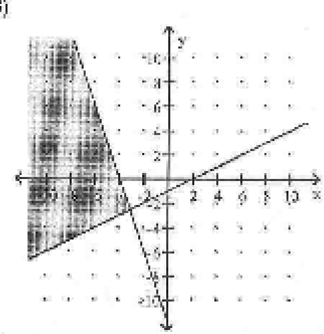
Graph the solution set of the system of inequalities or indicate that the system has no solution.

28) $2x - y \le 2$
$x + 3y \ge -12$

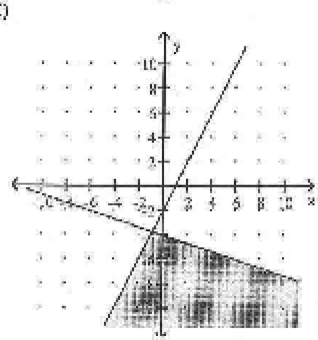
A)



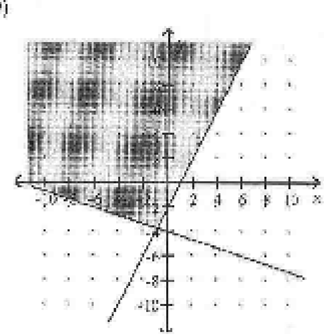
B)



C)



D)



C-8

Figure C-8. Page 8 of the departmental final exam for MAC 1105 for 2010-2011.

Solve.

29) The value of a particular investment follows a pattern of exponential growth. In the year 2000, you invested money in a money market account. The value of your investment t years after 2000 is given by the exponential growth model $A = 5200e^{0.055t}$. When will the account be worth $8378?

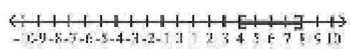
A) 2011 B) 2009 C) 2010 D) 2008

Solve the rational inequality and graph the solution set on a real number line. Express the solution set in interval notation.

30) $\frac{-x+8}{x-4} \geq 0$

A) $(-\infty, 8]$

B) $[4, 8]$



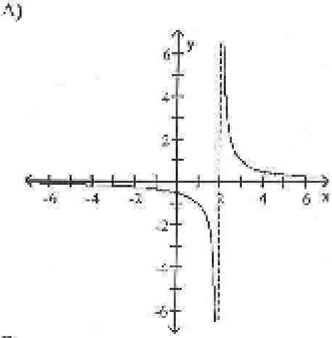
C) $(-\infty, 4)$ or $[8, \infty)$

D) $(4, 8]$

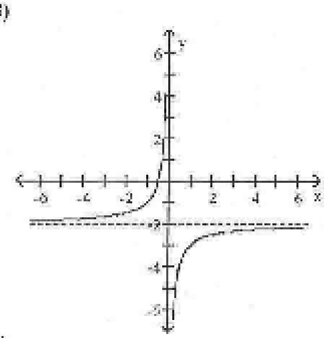
Use transformations of $f(x) = \frac{1}{x}$ or $f(x) = \frac{1}{x^2}$ to graph the rational function.

31) $f(x) = \frac{1}{x} - 2$

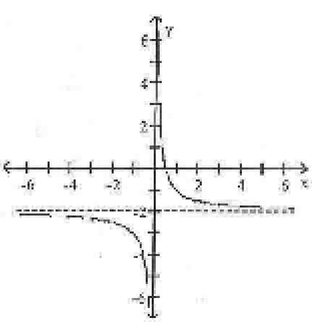
A)



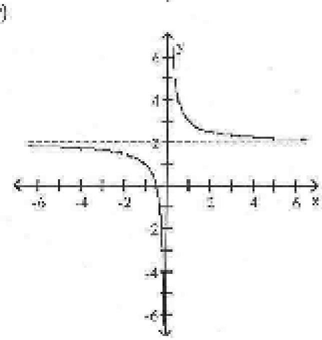
B)



C)



D)



C-9

Figure C-9. Page 9 of the departmental final exam for MAC 1105 for 2010-2011.

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BIOGRAPHICAL SKETCH

Paula Lee Gavin was born in Baltimore, Maryland, in 1968 to Craig and Justine Gavin. She grew up in Owings Mills, Maryland, before moving to Virginia to pursue her undergraduate work. Paula received her Bachelor of Science degree in mathematics from George Mason University in 1996 and her Master of Science degree in mathematics from Virginia Polytechnic Institute and State University in 1998. She has one son, Gavin Cifuentes, who was born in 1999. Paula worked as a research engineer for Science Application International Corporation for five years before moving to Florida to teach mathematics at Florida Gateway College (FGC) in 2002. She proudly won the 2004 Association of Florida Colleges *Professor of the Year* award for the state of Florida. Paula accepted a position as the Director of Academic Programs at FGC in 2012. In 2016, she received a promotion to the Dean of Academic Programs and the Baccalaureate Liaison at FGC, and she received her Ph.D. in curriculum and instruction from the University of Florida.