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The Impact of an Online, Mastery, and Project-Based Developmental Math Curriculum on Student Achievement and Attitude

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Dissertation Submitted in Partial Fulfillment

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Abstract

Due to anxiety, low confidence, and inadequate content knowledge, many college students struggle to complete their developmental math coursework. As colleges redesign their programs to address these issues, careful research is imperative to determine the factors that best meet the needs of these struggling students. The purpose of this study was to analyze the impact of one college's redesigned program (integrating online, mastery, and project-based learning) compared with the traditional program. Using Weiner's attribution theory of achievement motivation and emotion as a guide, this mixed methods case study used a quasi-experimental nonequivalent control group design in conjunction with a qualitative examination of student interviews. The study used archived quantitative data and interview data from community college students in the Western United States. The quantitative data was analyzed using multiple regression, and a thematic analysis was used for the interview data. The results indicated that students in traditional courses achieved higher final exam scores than those in the revised courses. However, the revised and traditional math students did not exhibit significantly different attitudes toward math. Some of the key factors that directly impacted student success included the availability of student support services, student collaboration, and self-concept and motivation. Based on these results, the participating college and similar colleges will be able to make more informed decisions to improve the efficacy of their developmental math programs. These revisions will then help to improve student attitude and success in mathematics, will motivate students to persist in their education, and will better equip students to positively contribute to their future communities and workplaces.

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Dedication

For her understanding, love, and unwavering support, my dissertation is dedicated to my dear wife. Thanks so much for having faith in me and for inspiring me to be more than I thought possible.

I love you, Jenny! <3

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Throughout my doctoral journey, I have had the honor of working with many amazing faculty, staff, and colleagues at Walden University. Each of my professors have committed countless hours teaching me what it means to truly be an educational scholar and a champion of change, and for their efforts, feedback, and encouragement, I am very grateful. In addition, my heartfelt thanks goes out to the members of my dissertation committee for their prompt, insightful feedback, their well-timed, sincere encouragement, and their unwavering devotion to my success. Last of all, a huge "Thank you!" goes out to my amazing family for their patience, understanding, sacrifice, and crazy humor. You have been my rock and my inspiration through it all.

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Chapter 1: Introduction to the Study

Many public community colleges throughout the United States have experienced tremendous growth in their developmental math programs. Much of this growth is due to the 30 to 40% of incoming freshman who require remediation and is further exacerbated as less than half of the developmental mathematics students are able to successfully complete each developmental math course with only one attempt (Snyder & Dillow, 2015; Trenholm, 2006). The developmental delays and failure rates of these students are largely a result of a long history of math struggles and the negative attitudes that are often strongly associated with those struggles (Cortes-Suarez & Sandiford, 2008; Feldman, Smith, & Waxman, 2014; Locklear, 2012; Weiner, 1985). As this cycle of failure in mathematics continues at the college level, student discouragement, hopelessness, and low self-concept often lead them to drop out of college without attaining their desired degree (Boylan, 2011; Feldman et al., 2014; Weiner, 1985).

In light of the research that has shown a strong correlation between student attitude and achievement (Aiken & Dreger, 1961; Chamberlin, 2010; Feldman et al., 2014; Hemmings, Grootenboer, & Kay, 2011; Moenikia & Zahed-Babelan, 2010), many colleges (including the community college participating in this study) have revised their developmental math programs in order to more effectively nurture positive attitudes and improve academic performance in students. As each of these innovative programs is carefully evaluated, educators and researchers will be able to identify the key elements that positively influence attitude (i.e. self-confidence, value, enjoyment, and motivation) and achievement (i.e. demonstrated understanding of math content directly tied to key course objectives), which will better inform future program revisions. The resulting revisions will then help to improve student attitudes and confidence in their abilities to learn mathematics, increase pass rates, decrease attrition and dropout rates, and help students to complete their college program of study more effectively and efficiently. Students will then be empowered with a greater capacity to positively contribute to their future communities and workplaces.

Chapter 1 begins with a synopsis of the main features, learning strategies, and challenges within many successful developmental math programs according to pertinent research literature. Gaps in this existing literature are then identified, followed by an explanation of this study's ultimate purpose, relevance, and framework. Then the main research questions are presented along with a discussion of the nature, limitations, and significance of this study.

Background

This section begins with a summary of research literature outlining the problem being addressed by this study. Next, the literature on online, mastery, and project-based learning approaches as well as research on student attitude towards mathematics are all closely examined to determine the overall gap in the literature. Then the need for this study is presented.

Summary of Research Literature

Many of the more traditional developmental math programs throughout the country are recognizing some major issues with their programs. First, the number of beginning college students in developmental mathematics courses is on the rise. Snyder and Dillow (2015) found that on average over a third of the incoming freshman in public 2-year and 4-year postsecondary institutions enrolled in remedial courses with the vast majority of them requiring math remediation. Furthermore, 2-year institutions specifically have shown trends where about half of the incoming freshmen require remediation (Complete College America, 2012). According to Boylan (2011), this growing need for math remediation was a result of inadequate math preparation in high school as well as elevated anxiety when working in mathematics.

In addition to this increased need and demand for math remediation, the excessive time required for many of these student to complete their remediation often results in student attrition. Demands to take (and often retake) multiple remedial courses can drag the time requirements for completing remediation across several semesters. As a result of getting trapped in remedial coursework, many students get discouraged, lose interest in finishing their education, or drop out entirely (Ashby, Sadera, & McNary, 2011; Hodara, 2015). According to Complete College America (2012), only 60 to 70% of incoming freshmen who need remediation actually complete their remedial coursework, and of those who do complete their remediation, fewer than half of them actually finish the associated college level courses. Most of the reform taking place in developmental mathematics at the college level is geared towards resolving these major issues of increased demand, delayed completion, and attrition. In order to attain a more holistic indication of how well these revised developmental math programs effectively resolve these issues, Chamberlin (2010) asserted that academic achievement and student attitudes should both be carefully assessed.

Gap in Literature & Need for Study

Many developmental mathematics program reforms have thoughtfully integrated online, mastery, or project-based learning approaches into curriculum in order to more effectively help students to develop positive attitudes and increased confidence towards mathematics, build strong academic proficiency, and actively apply the content within real-world contexts (Foutz, Navarro, Hill, Thompson, Miller, & Riddleberger, 2011; Guskey, 2007; Hoon, Chong, & Ngah, 2010; Locklear, 2012; Mioduser & Betzer, 2008; Movahedzadeh, Patwell, Rieker, & Gonzalez, 2012). While there are some gaps in the literature for each of these three learning approaches when explored individually, the gaps are substantially greater when examining the literature for research on developmental math programs that use all three learning approaches simultaneously. The following section more closely examines these gaps in the literature and identifies the need for research on programs that utilize online, mastery, and project-based learning approaches within a single curriculum geared towards improving student attitude and achievement.

Online learning. Many contemporary research studies have closely examined the use of online learning within developmental math programs and education in general. The vast majority of these studies included samples of students or teachers with diverse academic backgrounds in order to develop a broad understanding of the factors influencing faculty participation, factors leading to student success, and major challenges involved with online education (Armstrong, 2011; Baran, 2011; Hoffman, 2013; Jackson, Jones, & Rodriquez, 2010; Kaifi, Muftaba, & Williams, 2009; Locklear, 2012; Mosca, Ball, Buzza, & Paul, 2010; Shea, 2007; Wickersham & McElhany, 2010; Yousef, 2012). In addition, several studies specifically targeted science, technology, engineering, math, and business fields (Bressler, Bressler, & Bressler , 2010; Ernst, 2008; Neely & Tucker, 2010; Paadre, 2011; Parthasarathy & Smith, 2009). Of these studies, Paadre's (2011) study was the only one that targeted math students in particular in an effort to compare the performance of nine students who used an online program and those who did not. Thus, there is a need for additional research that targets the impact of online learning on math students specifically.

The grade level of participating students and teachers also indicates another gap in the research literature. With only a few exceptions, the vast majority of the research studies targeted students and teachers from universities or four-year colleges. These exceptions included two studies which targeted elementary students (Doering & Veletsianos, 2008; Shih, Kuo, & Liu, 2012), two studies that targeted high school students (Kim, Park, & Cozart, 2014; Paadre, 2011), one study that targeted students at a technical college (Pope, 2013), and two studies that targeted a two-year community college (Jackson et al., 2010; Xu & Jaggars, 2013a, 2013b). Thus, more research is necessary to better understand the impact of online learning on these sparsely represented populations.

Mastery learning. The recent research literature explored the impact of mastery learning on students studying a variety of academic subjects at a variety of grade levels. In particular, Athens (2011) and Wambugu and Changeiywo (2008) studied the impact of mastery learning on high school physics students, Frick, Frick, Coffman, and Dey (2011) focused on Doctor of Pharmacy students, Tatum and Lenel (2012) studied postsecondary psychology students, and Hoon et al. (2010) and Toheed and Ali (2011) studied middle school and high school mathematics students. Additionally, Rowe (2010) targeted community college students specifically but did not focus on one specific subject area. Taking the grade level and subject area combinations into account, a gap in the research literature on mastery learning exists for math students from community colleges. With the claims of Rowe (2010) and Guskey (2007) that mastery-based learning improves student attitude contradicting Frick et al.'s (2011) claims to the contrary, additional research should also explore the conditions and factors influencing student attitude within a mastery learning environment. Furthermore, quantitative research approaches were the main focus of each of the aforementioned mastery learning studies, leaving a gap to explore the impact of mastery learning from a qualitative lens.

Project-based learning. Current research studies pertaining to project-based learning used a variety of approaches (i.e. quantitative, qualitative, and mixed methods) and pulled samples of teachers and students from a variety of grade levels. However, only one study conducted by Movahedzadeh et al. (2012) specifically targeted students at a community college. Additionally, only one study conducted by Lee (2010) specifically targeted math courses although the participants were teachers rather than students. Thus, a gap exists in the literature for studying how project-based learning influences community college students studying mathematics.

Math attitude. While many researchers agree that student achievement and attitude in mathematics are strongly correlated (Aiken & Dreger, 1961; Feldman et al., 2014; Hemmings et al., 2011; Ma & Xu, 2004; Moenikia & Zahed-Babelan, 2010), many math programs tend to focus attention only on achievement, ignoring the impact of student attitudes on their academic success (Chamberlin, 2010). The research on student attitudes toward mathematics also tends to focus mainly on quantitative approaches. Feldman et al. (2014) conducted one of the few solely qualitative studies where they interviewed 53 youth dropouts in order to determine the factors that motivated their decisions to become truant and terminate their schooling. Swift's (2012) mixed methods study also included a qualitative component to more fully explore the impact of cooperative learning groups on the math attitude and achievement of pre-service elementary teachers. Furthermore, Swift (2012) conducted the only study related to attitudes toward mathematics within a community college environment. Therefore, the research literature also contains a substantial gap regarding qualitative research on community college math programs that closely examine student attitudes and achievement as measures of success.

Overall gap analysis. Based on the previously mentioned research literature, the areas of online learning, mastery learning, project-based learning, and math attitude all have very little research on students studying math at community colleges. The research on mastery learning and math attitude also showed a significant gap in qualitative research. In addition, while much of the previously mentioned research literature has described studies that have tested and analyzed the effectiveness of online, mastery, and project-based curricula, none of this research has explored the collective effects on integrating these three strategies within the same curriculum. To fill these gaps, the quantitative portion of this mixed methods study analyzed the program evaluation data archived by the participating community college for their developmental mathematics program. This analysis determined how student attitude and content knowledge at the end of a developmental mathematics course compared between students participating in the revised developmental math program and those participating in the traditional program. The qualitative component of this mixed methods study used student interview data to provide additional support for the quantitative findings and further determine specific program factors that influenced student attitude towards mathematics and achievement within the developmental math courses.

Social change may now follow as the results assist the participating college and other colleges with similar demographics to make crucial decisions necessary to maximize the success of their developmental math programs. These informed program changes may then nurture more positive attitudes as well as increased confidence in participating students, inspire students to persist in their education, and ultimately result in increased college degree completion rates among these students. Then, as graduates, these students may be better equipped and committed to make positive contributions to their future communities and workplaces.

Problem Statement

Many students within traditional developmental math programs (including that of the participating community college) struggle to complete their remediation in a timely manner as they continue to deal with issues of anxiety, low confidence in their math abilities, and inadequate content knowledge (Boylan, 2011). As a result, these remedial delays coupled with negative attitudes toward mathematics have led many students to lose hope in their abilities to succeed and drop out of school entirely (Ashby et al., 2011; Hodara, 2015; Trenholm, 2006). In an effort to resolve these student struggles and improve student persistence and success in their college programs of study, many colleges have revised their developmental math programs by integrating online, mastery, or project-based learning approaches into their curriculum. However, while there is recent research that shows the impact of these three learning approaches individually on student achievement and attitude (Foshee, 2013; Movahedzaheh et al., 2012; Rowe, 2010), there is a gap in the literature regarding the impact on student achievement and attitude on a community college developmental math program that simultaneously incorporates all three learning approaches.

Purpose of the Study

In order to address the aforementioned gap in the literature, this mixed methods case study analyzed how student experiences, academic achievements, and attitudes towards mathematics compared between the revised (i.e. single curriculum integrating online, mastery, and project-based learning approaches) and traditional (i.e. direct instruction, lecture-based learning approaches) developmental math courses at one community college in the Western United States. For the quantitative component of this study, the type of developmental math courses in which each student participated (revised or traditional) was the main independent variable in the multiple regression analysis. The initial attitude, initial content knowledge, the course instructor, course level (PreAlgebra, Beginning Algebra, Intermediate Algebra), student gender, and student ethnicity were included as independent variables in order to determine moderator effects. The dependent variables were the student attitude towards mathematics and content knowledge at the conclusion of each course.

Instruction methodology was included to determine if a student's participation in the revised or traditional versions of courses had a significant impact on their performance and attitude in the class. Attitude and content knowledge were included to assess how well the relationships described in Weiner's (1985) theory of attribution hold true for the participating community college developmental math students. The instructor and course level were included to determine how a student's instructor and the difficulty of a course influence the student's performance and attitude. As some research indicated that gender and ethnicity may be related to student success (Arslan, Canh, & Sabo, 2012; Kaifi et al., 2009), these two variables were included to determine the extent of these relationships in the context of this study.

In the qualitative portion of this study, one-on-one student interviews were conducted to gather details regarding the experiences of students while participating in the developmental math courses. This interview data provided additional context and support for the quantitative findings from the first two research questions. In addition these interviews were also the main source of student experiences used to address the third research question which helped to identify specific factors of the developmental math program that influenced student attitude and academic achievement. These quantitative and qualitative findings may now guide future developmental math program revisions and inform additional studies on the specific factors that impact the academic achievement and attitude of participating students.

Research Question 1

How does the final student content knowledge in revised developmental mathematics courses (integrating online, mastery, and project-based learning) compare with that of students in traditional developmental mathematics courses at one community college in the Western United States?

H_0: The final student content knowledge in revised developmental mathematics courses (integrating online, mastery, and project-based learning) is not significantly different from that of students in traditional developmental mathematics courses at one community college in the Western United States.

H_1: The final student content knowledge in revised developmental mathematics courses (integrating online, mastery, and project-based learning) is significantly different from that of students in traditional developmental mathematics courses at one community college in the Western United States.

Explanation of Variables

The main independent variable for research question 1 was the instruction methodology (revised or traditional). Initial attitude, initial content knowledge, instructor, course level (PreAlgebra, Beginning Algebra, Intermediate Algebra), student gender, and student ethnicity were also used in the multiple regression as moderator variables. The final student content knowledge was the dependent variable.

Initial and final attitude were measured using Tapia's (1996a, 1996b) Attitudes Toward Mathematics Inventory (ATMI) as a pretest and posttest. The four factors of math attitude measured via the ATMI are self-confidence, value, enjoyment, and motivation. The self-confidence items assess the level at which students associate anxiety, fear, and confidence with tasks involving mathematics. The value items assess the level at which students perceive math as necessary and important for everyday life. The enjoyment items assess the level at which students associate feelings of joy and happiness with the study and use of mathematics. The motivation items assess the level at which students seek out opportunities to engage in mathematics. Each ATMI item uses a Likert scale (i.e. strongly disagree, disagree, neutral, agree, strongly agree). For scoring purposes student responses were coded as 0, 1, 2, 3, or 4 with 0 representing the most negative attitude towards math and 4 representing the most positive attitude towards math. Then the pretest and posttest score for each student was computed using the sum of each coded response. Thus, as the ATMI contains 40 items, the minimum score possible was 0 and the maximum score possible was 160. The archived data acquired for this analysis contained only the composite attitude scores for each student. Subscale scores were not available.

A student's content knowledge refers to the student's understanding and mastery of fundamental mathematical concepts and skills based on the key course objectives. The key objectives of the PreAlgebra courses were for students to show proficiency with (a) arithmetic of signed numbers; (b) fractions, decimals, and percents; (c) order of operations; (d) unit conversions, rates, ratios, and proportions; (e) simplifying algebraic expressions; and (f) solving one- and two-step linear equations in one variable. The key objectives of the Beginning Algebra courses were for students to show proficiency with (a) solving and graphing linear equations in one and two variables; (b) solving linear inequalities in one variable; (c) arithmetic operations with polynomials; and (d) factoring polynomials. The key objectives of the Intermediate Algebra courses were for students to show proficiency with (a) functions; (b) solving and graphing linear inequalities in two variables; (c) solving and graphing absolute value equations and inequalities; (d) solving systems of linear equations involving two variables; (e) solving and graphing non-linear equations; and (f) performing arithmetic with complex numbers. The initial content knowledge of students was measured using a pretest composed of math problems directly tied to the aforementioned key course objectives of each developmental math course. These math problems were each in a multiple choice format, and the pretest score was the percentage of the test problems that the students answered correctly. Posttests were used as one measure of final content knowledge. These posttests were also composed of multiple choice math problems tied to the key course objectives. Final exam scores (composed of both multiple choice and short answer math problems) were also used to measure final content knowledge. The scores for the posttest and the final exam were also the percentage of the test problems that the students answered correctly.

Research Question 2

How does the final student attitude towards mathematics in revised developmental mathematics courses (integrating online, mastery, and project-based learning) compare with that of students in traditional developmental mathematics courses at one community college in the Western United States?

H_0: The final student attitude towards mathematics in revised developmental mathematics courses (integrating online, mastery, and project-based learning) is not significantly different from that of students in traditional developmental mathematics courses at one community college in the Western United States.

H_1: The final student attitude towards mathematics in revised developmental mathematics courses (integrating online, mastery, and project-based learning) is significantly different from that of students in traditional developmental mathematics courses at one community college in the Western United States.

Explanation of Variables

The main independent variable for research question 1 was the instruction methodology (revised or traditional). Initial attitude, initial content knowledge, instructor, course level (PreAlgebra, Beginning Algebra, Intermediate Algebra), student gender, and student ethnicity were also used in the multiple regression as moderator variables. The final student attitude towards mathematics was the dependent variable.

The Explanation of Variables section for Research Question 1 has more details regarding the attitude and content knowledge variables.

Research Question 3

How do students describe their experiences, attitudes, and content knowledge acquisition while participating in the revised and the traditional developmental mathematics programs at one community college in the Western United States?

Explanation

During one-on-one interviews, students were asked to share their experiences as they participated in the revised or traditional courses in the developmental math program. Specifically, students were asked to describe a typical class for their course, the elements of the class that helped or hindered their learning, and the emotions and attitudes that they experienced and associated with their developmental math courses. These experiences provided additional context and support to the quantitative findings from Research Questions 1 and 2 and also helped to identify specific factors of the developmental math program that influenced student attitude and academic achievement.

Theoretical Foundations

One overarching theory that frames this study is Weiner's (1985) attributional theory of achievement motivation and emotion. This theory indicates that motivation is typically dependent upon the causes that an individual attributes to an outcome. Furthermore, Weiner asserted that ability and effort are the most common perceived causes of achievement. Once a cause is identified, determinations are made regarding the locus, stability, and controllability of the cause. These determinations often directly impact the individual's self-esteem and attitudes, which could then result in the individual's continued persistence to achieve the desired outcomes or decreased motivation to persevere.

Many students who enter the developmental mathematics program at the onset of their college journey have had difficulty with mathematics in their past (Feldman et al., 2014). Thus, they have experienced firsthand the decreased motivation and hopelessness that result from seeing their lack of ability as an uncontrollable cause of their failure in mathematics (Feldman et al., 2014; Weiner, 1985). Based on Weiner's (1985) theory of attribution, a key factor to reigniting student hope for success lies in helping the student see how factors under the students' control (like effort) may influence their success more than factors (like ability or luck) over which the students have little or no control.

The purpose of this study was to determine if students developed a greater hope for success while participating in one community college's developmental math program and how much instruction methodology influenced that attitude change. By including attitude pretests and posttests, content knowledge pretests, final exam scores, and instruction methodology (revised or traditional) as key variables in the multiple regression analysis for this study, this purpose was achieved. In addition to providing additional context and support for these quantitative findings, student experiences gathered through one-on-one interviews also helped determine which key factors influenced the math attitudes and academic achievements of participating students. Knowledge of these influential factors and relationships will now guide future developmental math program changes in order to help students approach their learning with greater confidence, hope, and effort. Chapter 2 includes a more detailed explanation of Weiner's theory of attribution and how it frames this study.

Nature of Study

The three research questions for this mixed methods case study examine how the changes in attitude and content knowledge compare between students who participated in the revised and the traditional developmental math programs at the participating community college. The "Definitions" section of this chapter has a detailed description of the revised and traditional instruction methodologies. The first two research questions were addressed quantitatively using a quasi-experimental nonequivalent control group design as the analyzed archived data involved naturally assembled groups over which the researcher had no control (Campbell & Stanley, 1963). Within this design, a multiple regression analysis was used to determine the impact of instruction methodology on the final student attitude and acquired content knowledge while also accounting for the influence of other moderator variables. For the third question in this mixed methods case study, a qualitative approach was appropriate as it examined (via one-on-one interviews) student experiences while participating in the developmental math program (Creswell, 2013). This interview data provided additional context and support for the quantitative findings and helped to identify specific factors of the developmental math program that influenced student attitude and academic achievement. The quantitative and qualitative findings will now guide future developmental math program revisions and may inform additional studies on the specific factors that impact the academic achievement and attitude of participating students.

Variables

The main independent variable for quantitative research questions 1 and 2 was the instruction methodology (revised or traditional). Initial attitude, initial content knowledge, instructor, course level (PreAlgebra, Beginning Algebra, Intermediate Algebra), student gender, and student ethnicity were also used in the multiple regression analysis as moderator variables. The dependent variables were the final math attitudes and content knowledge of developmental math students. A more detailed explanation of these dependent variables appears in the Explanation of Variables section under Research Question 1 in this chapter.

Methodology Summary

Population. This study's target population included developmental math students at the participating Western United States rural community college. This student population is composed of approximately 56% females and 44% males, almost 85% White Caucasians, and about 92% state residents. Approximately 1500 students participate in the developmental math program at this college during each academic year. Thus, the program evaluation data archived over the course of 3 years represented approximately 4500 participating students. During each academic year, approximately 17 mathematics teachers taught about 70 developmental math courses. During the 2012-2013 academic year, 33% of the developmental math courses used the revised instruction methodology while 67% used the traditional instruction methodology. During the 2013-2014 and 2014-2015 academic years, 67% of the developmental math courses used the revised instruction methodology while 33% used the traditional instruction methodology. In addition, of all the developmental math courses taught from 2012-2015, approximately 20% were PreAlgebra, 25% were Beginning Algebra, and 55% were Intermediate Algebra.

In order to bypass the developmental math program, incoming students at the participating college needed to meet at least one of the following criteria: earn 23 or higher in the math section of the ACT, earn 540 or higher in the math section of the SAT, earn 90 or higher on the Accuplacer: Elementary Algebra test, or earn a 50 or higher on the Accuplacer: College Level Math test. All students who did not meet at least one of the aforementioned criteria were required to participate in the development math program, and were placed in one of the developmental courses (PreAlgebra, Beginning Algebra, Intermediate Algebra) based on their criteria scores. Students in the developmental math program were required to pass each class with a C or better in order to move on to the next course.

Based on standard procedures and policy at the college, identical course descriptions were used for both the revised and traditional sections of each developmental math course in the print and online course catalog. Thus, students who registered for developmental math courses based only on the course name and description assigned themselves to a revised or traditional course section without prior knowledge of the content delivery method. Although students were still allowed to change their schedule during the first few weeks of classes, most students remained in the class in which they had originally enrolled. Even though the researcher had no control over which students enrolled in the revised or traditional courses, some randomness was achieved due to this process implemented by the college using identical course descriptions for both types of courses. In addition, the content covered in both the revised and traditional developmental math courses at each level was the same.

Data collection. Quantitative and demographic data archived by the participating math department and college were used in this study. The student academic achievement was measured using the content knowledge pretest and posttest scores and final exam scores. The student attitude towards mathematics was measured using attitude pretest and posttest scores. Tapia's Attitudes Toward Mathematics Inventory was used as the attitude pretest and posttest. Additional archived data analyzed in this study included student gender, ethnicity, course instructor, and course level (i.e. PreAlgebra, Beginning Algebra, and Intermediate Algebra). Interviews of participating students were also conducted for this study. More details on the participant selection strategies for these qualitative interviews are provided in Chapter 3.

Data analysis. The quantitative quasi-experimental portion of this research study employed statistical tests similar to those used in true experimental designs (Schenker & Rumrill, 2004). Therefore, a nonequivalent control group design was used. Within this design, a multiple regression analysis was conducted to determine how much the instruction methodology (revised or traditional) impacted the final content knowledge and attitude of students who participated in the revised and traditional developmental math program. Initial attitude, initial content knowledge, instructor, course level (PreAlgebra, Beginning Algebra, Intermediate Algebra), student gender, and student ethnicity were also included in the multiple regression to account for potential moderating effects. In addition, the student interview data collected during the qualitative portion of this study were coded and analyzed to more closely examine the students' experiences while participating in the revised and traditional developmental math programs.

Computer software (Microsoft Excel and SPSS) was used to find the student enrollment in the traditional and revised developmental math programs for each semester from Fall 2012 to Spring 2015, the total number of developmental math courses taken for each student, and additional descriptive statistics and graphics from the original data as needed. Next, a multiple regression was conducted to determine how much the instruction methodology, initial attitude, initial content knowledge, instructor, course level, student gender, and student ethnicity influenced the final attitude and acquired content knowledge of students. Then within the NVivo software, matrix coding, word frequency queries, and code queries were used on the interview transcripts to develop the initial node structure and identify overarching themes in the qualitative data

Definitions

College-level mathematics: Math courses (often required for a specific program of study) taken after all math remediation is completed (Bailey, Jeong, & Cho, 2009). The introductory college-level math courses at the participating community college include Quantitative Literacy, Introduction to Statistics, College Algebra, and PreCalculus.

Content knowledge. A student's content knowledge refers to the student's understanding and mastery of fundamental mathematical concepts and skills based on the key course objectives. More details regarding these key course objectives appear in the Explanation of Variables section under Research Question 1.

Developmental mathematics: Math courses which imbue students with the foundational knowledge, skills, and experiences that will prepare them for college-level mathematics (Bailey et al., 2009; Hendricks, 2012; Spradlin, 2009). At the participating community college, PreAlgebra, Beginning Algebra, and Intermediate Algebra are considered to be developmental mathematics courses as the content in these courses is considered to be at a secondary level.

Mastery learning: According to Slavin (1987), Block and Anderson (1975), and Bloom (1976), mastery learning refers to instructional methodologies which utilize feedback, assessments, and instruction to enable students to achieve a set level of mastery for specific skills and concepts.

Online learning: Although several definitions of online learning have been proposed, this study defines online learning as learning experiences facilitated through the use of technology (Benson, 2002; Carliner, 2004; Conrad, 2002; Moore, Dickson-Deane, & Galyen, 2011).

Project-based learning: Though multiple definitions of project-based learning exist, the definition adopted for the current study is a learning approach which centers the learning experiences of students around engaging activities and problems designed to give context to content (Graaff & Kolmos, 2007).

Remedial mathematics / math remediation: For the scope of this study, these terms are synonymous with developmental mathematics (McHugh, 2011; Stigler, Givvin, & Thompson, 2010).

Remediation: The process of addressing cognitive skills deficits (Hendricks, 2012).

Revised/new developmental math courses: Developmental math courses at the participating college were taught using online, mastery-based content delivery in conjunction with regular, face-to-face projects and problem-solving activities. These courses utilized the iLearn Math web system developed by iLearn, Inc., for the online content delivery. Within this online system, a combination of verbal, textual, and animation strategies were used to teach students each lesson. Following the instruction students would complete associated math problems and take mastery assessments at the end of each lesson, chapter, and unit. Once students demonstrated sufficient mastery (by scoring at least an 80% on the mastery assessment), they were allowed to move on in the content. If students scored less than an 80% on a mastery assessment, they would be allowed to go through the lesson again and would be given additional practice problems prior to retaking the mastery assessment. This online content delivery system also gave students a challenge test before each unit, chapter, and lesson. If students earned a 90% of higher on a challenge test, they would skip the associated content, allowing them to only spend their time learning the material that they had not previously mastered.

For the project-based component of the revised developmental math program, each teacher would select and administer a project or activity to their classes each week (outside of the iLearn system) in order to give students further practice with learned concepts and additional experience in applying mathematical knowledge and skills within real-world contexts. These projects and activities were chosen by the instructors based upon the student needs within each course.

Student attitude: Based on Tapia's Attitudes Toward Mathematics Inventory, student attitude in the context of this study refers to the self-confidence, value, enjoyment, and motivation exhibited by mathematics students. The self-confidence items assess the level at which students associate anxiety, fear, and confidence with tasks involving mathematics. The value items assess the level at which students perceive math as necessary and important for everyday life. The enjoyment items assess the level at which students associate feelings of joy and happiness with the study and use of mathematics. The motivation items assess the level at which students seek out opportunities to engage in mathematics. Each ATMI item uses a Likert scale (i.e. strongly disagree, disagree, neutral, agree, strongly agree). For scoring purposes student responses were coded as 0, 1, 2, 3, or 4 with 0 representing the most negative attitude towards math and 4 representing the most positive attitude towards math. Then pretest and posttest scores for each student were computed using the sum of each coded response. Thus, as the ATMI contains 40 items, the minimum score possible was 0 and the maximum score possible was 160.

Traditional developmental math courses: Developmental math courses at the participating college were taught using a more traditional lecture style for content delivery (Hendricks, 2012; Spradlin, 2009). Teachers of these traditional courses would use predominantly direct instruction techniques during class to teach students about the mathematical concepts. These courses would typically present mathematical content in the order presented in the course textbook. Students would be assigned homework for each textbook section, and at the end of 1 or 2 chapters, an exam would be administered. The course final exam given to students at the end of each semester was the same for all revised and traditional courses of the same level.

Assumptions

For this study, one assumption was that I would be granted access to the required secondary data from the participating community college. It was reasonable to assume I would be granted access to the data throughout the duration of this study in light of the fact that the results would supplement the college's ongoing evaluative efforts regarding their revised developmental math program. Additionally, I assumed that the participating students provided truthful responses and exerted their best effort when completing the content and attitude assessments. As the assessments used provided students with a direct or indirect snapshot of their achievement of essential course learning outcomes and their own perceptions and attitudes towards the subject matter, it was reasonable that this assumption would hold. Another assumption was that the secondary data used in the study provided a representative snapshot of the academic achievements, attitudes, and demographics of the participating students.

Scope of the Study

This study utilized archived data from an open enrollment public institution in conjunction with student interviews to determine how much of the variation in attitudes and achievement of students can be explained by instruction methodology (revised or traditional), initial attitude, initial content knowledge, instructor, course level (PreAlgebra, Beginning Algebra, Intermediate Algebra), student gender, and student ethnicity for students participating in the developmental mathematics program. The analysis excluded data for students who withdrew from a course. The participating students were approximately 56% females and 44% males, 85% White Caucasians, 65% full-time students, and about 92% state residents. As the revised developmental math program being studied incorporated online, mastery, and project-based learning into a single curriculum, conclusions drawn from the relationship between instruction methodology and student attitude or acquired content knowledge pertain mainly to a single math curriculum containing a combination of all three instructional strategies. Furthermore, the study results can only be generalized to colleges with dynamics and demographics similar to that of the participating college and developmental math programs similar to the one being studied.

Limitations

As the quantitative data being analyzed in this study is secondary in nature, I was not able to control for optimal data collection methodologies, preventing the use of a true experiment design. Therefore, the use of this secondary data limited the research design options to quasi-experimental or correlational designs. However, as I also work at the participating community college as a full-time faculty member, the analysis of this archived data allowed me to most ethically address the quantitative research questions while minimizing risks to the students that I may know or may have taught. During this study, I was not able to influence participating student grades for their developmental math courses as all grades were finalized at the end of Spring 2015. To further minimize these risks and confidentiality issues, the archived data had all identifiers unique to specific students removed prior to being entrusted to me. In addition, as the qualitative interviews took place approximately 2 years after the students completed the developmental mathematics program, the students' ability to recall their developmental mathematics experiences was also a limiting factor to this study. However, this time lapse between completion of the developmental math program and participation in the interview further ensured that I was not able to influence past, present, or future grades for the students as most of them had completed their academic programs at the participating community college.

While many researchers acknowledge that quasi-experimental designs can be worthwhile alternatives to true experiments due to ethical, political, or practical conditions outside of the researcher's control or when using secondary data, they also agree that this design is more restrictive in terms of generalizability of results (Campbell & Stanley, 1963; Charters, 2013; Eccles, Grimshaw, Campbell, & Ramsay, 2003; Grimshaw, Campbell, Eccles, & Steen, 2000; Williams, 2013). With the use of well-established quantitative methods and strategies coupled with the additional insight and clarification offered from the qualitative interview analysis, these issues of validity and generalizability can be mitigated (Bray, Schlenger, Zarkin, & Galvin, 2008; Brewer, 2012). Chapter 3 gives a more thorough account of the methodologies and strategies used in this study to address these issues. In light of these considerations, the generalizability of this study is limited specifically to colleges who are implementing or are planning to implement a similar developmental math program and who have demographics comparable to the participating college.

Significance

With the advent of many revised and innovative developmental mathematics programs at the college level, current research needs to closely examine how effectively and efficiently each program helps students to achieve their academic goals. The literature on online learning, mastery learning, project-based learning, and attitude towards mathematics in these program evaluation efforts has shown critical gaps in qualitative and mixed methods research at community colleges that examines developmental math programs which combine all three learning approaches (i.e. online, mastery, and project-based learning). In order to address this literature gap, this study examined how various characteristics of such a program interact with student attitude and achievement using a mixed methods approach. The results will guide future research and developmental math program revisions in order to increase the success with which the programs promote student learning and positive attitudes towards mathematics and academics in general. The increased confidence, self-efficacy, and success of these students will then serve as a catalyst that will motivate them to complete their degrees, become responsible contributing members of the communities in which they live, and effectively apply their skills, knowledge, and positive influence within their future careers.

Summary

As the demand for developmental mathematics coursework in community colleges continues to increase, many colleges have designed and implemented revised programs which focus of improving the learning and attitudes of participating students. Using Weiner's attribution theory of achievement motivation and emotion as a guide, this mixed methods case study used a quasi-experimental nonequivalent control groups design in conjunction with a qualitative examination of student experiences based on interviews to determine how the final student attitude and content knowledge compare between students participating in the revised developmental math program and those participating in the traditional program. This study will motivate positive social changes as the results assist the participating college and other colleges with similar demographics to make crucial decisions that will improve the success of their developmental math programs. Furthermore, the resulting program revisions will nurture more positive student attitudes towards mathematics, help increase student confidence in their abilities to succeed, and motivate students to persist in their education and complete their program of study. These students will then be better equipped and driven to make positive contributions to their future communities and workplaces.

In the following chapter, a more thorough review of the pertinent research literature is provided. This review begins with a detailed explanation of the research strategies used followed by an in-depth review of this study's theoretical framework. The chapter concludes with an account of the research literature that relates to the chosen methodology and variables used in this study.

Chapter 2: Literature Review

For many young students, learning math in school begins as an exciting experience even if they struggle to master some new math concepts. However, according to Feldman et al. (2014), these experiences in math often take a drastic turn as the students enter secondary school and face the more abstract concepts of algebra. As their struggles with math grow, these students begin to associate negative attitudes and emotions (i.e. anxiety, hopelessness, low self-confidence, etc.) with their math classes and experiences. When these students move on to pursue their dreams of a college education, they are faced once again with the seemingly impenetrable wall of developmental mathematics which bars their way to completing their desired programs of study. In fact, over a third of the incoming college freshman require such remediation in mathematics, and over half of these students fail their first attempt at these required developmental math courses (Snyder & Dillow, 2015; Trenholm, 2006). These students find themselves in a destructive cycle where the negative attitudes lead to discouragement and failure, which then exacerbates the negative attitudes and often leads to the decision to drop out of college entirely (Ashby et al., 2011; Hodara, 2015; Trenholm, 2006).

As these issues of anxiety, low confidence, failure, and attrition become increasingly prevalent for students within traditional developmental math programs (Ashby et al., 2011; Boylan, 2011; Hodara, 2015; Trenholm, 2006), many colleges are seeking to counteract these negative trends by revising their programs to include online, mastery, or project-based learning strategies. Each of these strategies has been shown in recent research studies to have an impact on student attitude and achievement (Foshee, 2013; Movahedzaheh et al., 2012; Rowe, 2010). However, there has not yet been any research that examines the influence of a single program that integrates all three of these learning strategies. Fortunately, one community college in the Western United States has implemented such a program, and this mixed methods study analyzed the impact of this program on student achievement and attitudes.

This chapter opens with a detailed description of the search strategies used to gather the foundational literature for this study. Then a thorough examination of the study's theoretical foundations is presented along with a detailed review of the research literature connected to the key constructs and methodology used in the study.

Literature Search Strategy

A meticulous search strategy was used to explore existing research literature and find the literature that would best inform this study. This section provides a detailed explanation of the library databases, search engines, and key search terms used for the literature review. In addition, the scope of the literature review is provided.

Library Databases and Search Engines

The Walden University library was the initial source for my literature searches for this study. The major educational and multidisciplinary databases available through the library included ERIC, Education Research Complete, Academic Search Complete, SAGE Premier, and ProQuest Central. ProQuest Central was also the main database that I used to search through completed dissertations and theses. After first searching through the aforementioned databases, I then used Google Scholar to find additional literature pertaining to the study.

Key Search Terms

My preliminary literature searches were focused on the key learning approaches (i.e. online, mastery, and project-based learning) incorporated in the revised developmental math program at the participating community college. My opening search was the most stringent, looking for research articles that referenced online, mastery, and project-based learning (including synonyms for each of these learning approaches) as well as developmental or remedial math. Upon finding no articles that referenced all three learning approaches, I then relaxed my search criteria by searching for one learning approach at a time as it related to developmental or remedial math. Then I relaxed the search criteria further to include articles that referenced online, mastery, or project-based learning strategies used in math and other subjects in middle schools, high schools, and general college populations. The resulting research articles were then analyzed for findings that reflected the benefits, challenges, and characteristics of effective implementations for each of the learning approaches.

Next, I conducted additional searches that focused specifically on developmental and remedial program redesign for math and other subjects at the college level. I used the articles resulting from this search to determine why the redesigns were needed, why increasing numbers of students require math remediation, program challenges and motivators for change, and characteristics of effective revised programs. In order to find primary sources for statistics pertaining to college level math remediation and remediation in general, I also searched the websites of the National Center for Education Statistics and Complete College America. I searched these statistics sites on multiple occasions to ensure that the statistics remained as current as possible.

The theoretical foundations of each of these articles were also closely analyzed, and I specifically searched for additional articles that used and explained the referenced theories in order to determine a framework for this study. These theoretical searches focused mostly on theories that related student attitude and achievement as most of the articles already compiled on learning strategies within developmental or remedial mathematics used data on attitude and achievement in their analyses. My successive searches focused on finding research that referenced the attitudes that student had toward mathematics, instruments that measured those attitudes, and connections between attitude and achievement.

Last, I searched the literature for research that related specifically to the methodology used for this study. Specific key terms that I used for this search included *secondary or archived data*, *quasi-experimental design*, and *non-experimental design*. Then I filtered the resulting literature articles to include only those articles pertaining to math education or education in general.

Scope of Literature Review

All searches were initially limited to include literature published since 2010. Depending on the quantity of relevant hits within this timeframe, the publication year restrictions were relaxed as needed. Seminal research articles were also used based on the references of the current research articles already found. Where possible, the original articles or books were also used in order to reference the theoretical framework and key learning approaches involved in this study. Scholarly and peer reviewed journals were the predominant sources of articles for the literature review.

Theoretical Foundations

One overarching theory that framed this study is Weiner's (1985) attributional theory of achievement motivation and emotion. According to this theory, a person's motivation and persistence depends upon the perceived causes of a certain outcome (Dasinger, 2013; Weiner, 1985). When Heider (1958) first proposed a theory of attribution, he identified the initial dimension of causality to be the locus of causality where an individual perceives an outcome to stem from internal causes like ability or effort or from external causes like the environment or luck. Weiner (1985) added two additional dimensions of causality to his attributional theory in order to also account for the stability and the controllability of perceived causal factors. The perceived causality and expectancy of future success then directly influences the student's sense of self-efficacy and motivation for future academic achievement (Bandura, 1977; Cortes-Suarez & Sandiford, 2008; Locklear, 2012; Weiner, 1985). Thus, students who determine that a failure results from an internal, stable, uncontrollable cause (i.e. ability) will tend to expect the same outcome each time regardless of any efforts they make to change it, resulting in decreased effort, a diminished sense of self-efficacy, and increased anxiety (Cortes-Suarez & Sandiford, 2008; Dasinger, 2013; Locklear, 2012). However, students who determine that a failure results from an internal cause that is both unstable and controllable (i.e. effort) will view the failure as preventable and take steps to improve the outcome in the future (Dasinger, 2013).

This attribution theory of achievement motivation and emotion is especially well suited to frame studies that seek to examine and explain academic performance in mathematics classrooms (Cortes-Suarez & Sandiford, 2008; Middleton & Spanias, 1999;

Locklear, 2012). Feldman et al. (2014) interviewed 53 youth volunteers in order to determine the experiences and perceptions that led them to drop out of school. Many of these students reflectively noted that they had positive attitudes toward math during their elementary school years even though some struggled with some math concepts, demonstrating a perception that their failures were caused by unstable, controllable factors. However, as they entered middle school and high school and began to learn more difficult and abstract math concepts (i.e. algebra), these perceptions typically changed dramatically as they buckled under the increased demands on time, effort, and cognitive ability (Feldman et al., 2014). At this stage in their mathematical development, these students began to look at their struggles as unavoidable due to an ability deficit rather than a lack of effort. Thus, they found themselves in a downward spiral of hopelessness, diminishing self-efficacy, and growing anxiety (Cortes-Suarez & Sandiford, 2008; Feldman et al., 2014; Locklear, 2012; Weiner, 1985).

The qualitative findings of Feldman et al. (2014) validated earlier quantitative findings of Cortes-Suarez and Sandiford (2008) and Dasinger (2013). Cortes-Suarez and Sandiford (2008) gathered and compared attributional data from 410 College Algebra students. Analyses on the data confirmed that the causes that students attributed to their performance were significantly different for the passing and failing students. Passing students attributed their performance to controllable factors while failing students attributed their performance to external, uncontrollable factors. Dasinger's (2013) study of 488 community college students in Intermediate Algebra courses led to the same conclusions.

Such is the state of many of the students who are placed in developmental mathematics programs as they begin college. Therefore, a major goal for revising these programs should be to replace self-defeating, negative attitudes with hopeful, self-enhancing attitudes (Locklear, 2012). Through continued research and evaluation, the factors and program elements that contribute or distract from this major goal can be identified and revisions can be designed and implemented to improve student attitudes and academic performance. This study determined if the hope to succeed can be rekindled for these students as they engage in the revised developmental math program at the participating community college. Based on Weiner's (1985) theory of attribution, a key factor to reigniting student hope for success lies in helping the students see how their effort may be contributing more towards their success or failure in mathematics than lack of ability.

Developmental Math Reform

This section outlines the struggles faced by students in developmental mathematics programs and the need for informed change in these programs to better meet student needs. Then an explanation of the complex interactions between student achievement and attitude within these programs is provided. Last, the need for additional research to best guide these revisions is explained.

Student Struggles and the Need for Change

Students in developmental math programs in college often have experienced a long history of struggles in mathematics. In interviews with 53 youths (ages 16 to 20) who had become extremely truant or had dropped out of school entirely, Feldman et al. (2014) were able to discover some potential sources for many of these struggles. Many of these youth acknowledged that their issues and failures in math had a tremendous impact on their decisions to give up on their schooling. Even though they typically struggled with math even at the elementary school level, most of these youths began to develop negative attitudes towards math in middle school or early high school when they were introduced to algebra and other abstract mathematical topics (Feldman et al., 2014). As the demands for consistent effort, mental focus, and time grew in these more complex math classes, these students became increasingly frustrated and hopeless as they continued to fail in spite of their efforts to improve (Feldman et al., 2014). In a qualitative study that examined the experiences and perceptions of 13 struggling developmental math students, Cordes (2014) also found similar ties between these increasingly negative attitudes and student failure in mathematics. As a result of these recurring failures, these students lost faith in their abilities to succeed and developed an increasingly negative mindset towards math and academics in general, which ultimately led to feelings of low self-efficacy, decreased confidence, and poor academic performance (Aiken & Dreger, 1961; Cordes, 2014; Feldman et al., 2014; Hemmings et al., 2011; Shively & Ryan, 2013).

In spite of their previous struggles with math, a lot of students still choose to pursue higher education. However, these students run into a major impediment to their college dreams as they are placed in remedial math courses before they can begin their coursework in college-level mathematics. In fact, over 30% of the incoming freshman in public 2-year and 4-year postsecondary institutions enrolled in remedial courses, with the vast majority of them requiring math remediation (Snyder & Dillow, 2015). At this early juncture in their college career, the negative attitudes, anxiety, low self-efficacy, and poor mathematics preparation from high school are present once again and are exacerbated by developmental math programs that take too long to complete, inadequately identify and address the gaps in the students' mathematics understanding and reasoning, and fail to meaningfully connect the learned mathematics content to life and experiences outside the classroom (Boatman, 2012; Boylan, 2011; Hendricks, 2012; Kirst & Bracco, 2004; Ma & Xu, 2004; McGlaughlin, Knoop, & Holliday, 2005; Stigler et al., 2010). Left unchecked, the students' negative attitudes and poor mathematics achievement feed off of each other, and many students become discouraged, lose interest in finishing their education, and drop out entirely (Ashby et al., 2011; Hodara, 2015).

Colleges throughout the country and the world have noticed these issues of attrition, negative attitudes, and poor achievement within their traditional developmental math programs and have made significant revisions to these programs in order to more effectively help this important population of students to succeed at the college level (Ashby et al., 2011; Bailey et al., 2009; Boatman, 2012; Kirst & Bracco, 2004). As each of these innovative changes are implemented and evaluated, the field of developmental mathematics gains much needed insight into the strategies, environments, and practices that have and have not been successful.

Roles of Attitude and Achievement

Based on Tapia's (1996a, 1996b) and Tapia and Marsh's (2002) development and analysis of the Attitudes Toward Mathematics Inventory, student attitude in the context of this study refers to the self-confidence, value, enjoyment, and motivation exhibited by mathematics students. While the vast majority of developmental math program evaluations tend to focus largely on student achievement as a gauge for success, many evaluators, educators, and researchers are also recognizing a reciprocal relationship between student attitude and performance (Cordes, 2014; Duatepe-Paksu & Ubuz, 2009; Feldman et al., 2014; Gamble, 2011; Hemmings et al., 2011; Ma & Xu, 2004; Rice, Barth, Guadagno, Smith, & McCallum, 2012). For example, Cordes (2014) conducted a phenomenological study of 13 students who failed their developmental math courses to determine connections between experiences, attitudes, and performance for these students. From student interviews and questionnaires, Cordes concluded that negative attitudes toward math, self-doubt, and low confidence all were linked to the students' perceptions of their abilities and their overall performance. These findings corroborated the qualitative conclusions of Feldman et al. (2014) who worked with students between the ages of 16 and 22.

From a quantitative ANOVA analysis of math test scores from 100 Australian secondary school students, Hemmings et al. (2011) were also able to confirm that attitudes were strong predictors of math performance in sophomore students specifically. In a similar quantitative study of 3116 secondary students, Ma and Xu (2004) also found correlations between attitude and achievement of secondary school students, but they also concluded that attitude was affected more by achievement than achievement was by attitude. Chamberlin (2010) also asserted that attitude and achievement should both be assessed to provide a holistic account of student performance within a mathematics classroom. This assertion coincides with Wiener's (1985) attributional theory which illustrates the reciprocal relationships between attitude, motivation, and achievement. Therefore, monitoring and controlling student attitudes as well as content knowledge acquisition could greatly impact student performance within a class (Chamberlin, 2010).

In a mixed methods study that used middle school student interviews in conjunction with achievement data to determine the effectiveness of a drama-based geometry unit, Duatepe-Paksu and Ubuz (2009) were able to affirm that a deeper and more complex view of student learning could be achieved when attitude and achievement data were both examined together. From a quantitative analysis of achievement pretest and posttest scores and attitude survey results, Gamble, Kim, and An (2012) also found that a middle school math academy program improved math readiness, interest, overall attitude toward learning, and self-concepts. Similarly, Gamble (2011) found that differentiated instructions had a significant impact on fifth grade student attitude compared with traditional instruction. Other studies also found that motivational videos and student support had a substantial effect on college student attitudes (Hodges & Kim, 2013; Rice et al., 2012). Furthermore, Graesser et al. (2008) conducted a mixed methods study which explored the interactions between the emotions of 7 undergraduate university students and the dialog of an automated, online physics tutor system, and they learned that the feedback characteristics of the online tutor had a significant impact on the affective state (i.e. confusion, delight, and frustration) of the students.

In contrast, Swift's (2012) mixed methods study of 500 students in a community college teacher education program showed no significant differences in either attitude or achievement between groups taught using different teaching styles (i.e. cooperative or traditional). Likewise, in a quantitative analysis of survey data and school records from 395 second year business students at a Philippine university, Yu (2011) also concluded that attitude had little influence on performance. Furthermore, even though Hodges and Kim's (2013) study did show that motivational videos had a significant impact on student attitudes, the videos did not have a significant impact on student interest or achievement. Yushau's (2006) study on pre-calculus students also showed no significant change in attitude from blended instruction although participants did have a predominantly positive attitude towards math and computer. In addition, other discrepancies have been found when determining the influence of specific student demographics (i.e. gender, age, etc.) and backgrounds on student attitude. For example, Arslan et al. (2012) and Hemmings et al. (2011) both found that gender had a significant influence on math attitude while Ma and Xu (2004) and Moenikia and Zahed-Babelan (2010) found that gender had no significant influence on math attitude. Thus, current research paints a very complex picture of the interactions between student achievement and attitude, and additional research is imperative to help clarify these findings.

Research Needs

Although mathematics is one of the content areas most related to affect, there is still a great shortage in data and research involving the relationship between student attitudes and learning mathematics (Chamberlin, 2010). Also Swift's (2012) study was the only one to specifically analyze students within a community college setting. Additional research is needed to fill this gap, especially at the community college levels, and clarify the causes for some of the discrepancies that exist in the current research. Furthermore, while many helpful contributions have been made by quantitative studies, there are only a few studies that used a qualitative or mixed methods design (Duatepe-Paksu & Ubuz, 2009; Feldman et al., 2014; Rice et al., 2012). Therefore, some additional qualitative studies would be helpful in providing further insight and perspective on the most significant factors that influence student attitude and achievement. Identifying, monitoring, and controlling these factors will then help to further improve the effectiveness and efficiency with which developmental math programs are able to address student needs.

Online Learning

As no research has been conducted that examines the efficacy of a single developmental math curriculum that integrates online, mastery, and project-based learning, the next sections examines the research that focuses on each of these strategies individually. The first of these teaching strategies involves online learning. Online learning started gaining momentum in the education community in the 1980's and 1990's due to several technological advances (including the advent of the world-wide web) (Haram, 2000). Although several definitions of online learning have been proposed, this study defines online learning as learning experiences facilitated through the use of technology (Benson, 2002; Carliner, 2004; Conrad, 2002; Moore, Dickson-Deane, & Galyen, 2011). As online learning continues to grow in prominence throughout the educational world, researchers and educators are striving to gain more insight into the motivating factors and benefits that lead teachers and students to embrace online education (Baran, 2011; Hoffman, 2013; Locklear, 2012; Shea, 2007; Shih et al., 2012). Other researchers have also unveiled many of the educational challenges (i.e. motivation, interaction, and collaboration) faced by online students (Kim et al., 2014; Mosca et al., 2010; Xu & Jaggars, 2013a, 2013b). This section specifically explores the benefits, challenges, and best practices of online learning based on recent research literature. Then the gaps in this literature and the specific needs for additional research are identified.

Benefits

Through interviews with six online program coordinators and university teachers from the Midwestern United States, Baran (2011) found that some of the factors that motivate online teachers include previous experiences with online education, institutional rewards, technology enhanced learning environments, the pedagogical support, intellectual challenge, and the added flexibility that online teaching offers. From a correlational study of 142 university faculty members, Hoffman (2013) expanded this list of teacher motivators to also include the perceived efficacy of online education and the desire to make education more accessible to students. Through their quantitative analysis of questionnaire data gathered from 60 university faculty, Parthasarathy and Smith (2009) also concluded that many teachers taught online in order to improve the marketability and image of their school. Thus, whether taught solely online or as a hybrid with online and face-to-face components, many classes and schools in general are embracing online learning as a means to offer increased flexibility and accessibility for both students and teachers, promote institutional growth, offer a stimulating challenge as well as professional growth to teachers, and contribute to a more positive school image (Baran, 2011; Hoffman, 2013; Parthasarathy & Smith, 2009; Shea, 2007; Wickersham & McElhany, 2010).

In addition to the aforementioned motivators for online teachers, several studies have also found online education to have significant benefits for students as well. For example, in a quantitative quasi-experimental study of 281 students attending liberal arts math courses, Locklear (2012) found that administering homework in an online environment significantly increased the homework completion rates compared with students who completed traditional written homework. From a quasi-experimental analysis of diagnostic test scores and math connection ability questionnaires from 118 fifth grade students in Taiwan, Shih et al. (2012) also found that an online personalized content delivery system improved student achievement and problem-solving skills more than students who learned via traditional classrooms settings. In contrast to the previously mentioned studies that found significant student benefits from online education, Paadre's (2011) mixed methods analysis of survey, interview, and test data from ninth grade technical high school students led to a conclusion that students were equally successful in online, hybrid, and traditional courses. Pope's (2013) quantitative analysis of 697 technical college students also verified Paadre's findings at the college level. Pope's work also added to the previous work of VanLehn et al. (2007) who conducted seven different experiments to determine how human tutoring, online automated tutoring systems, and canned text remediation impacted the learning gains of participating university students. VanLehn et al. concluded that the online tutoring systems yielded the same level of learning gains as human teaching and tutoring.

Challenges

In spite of the many benefits that have been found with online education, there have also been many challenges for both teachers and students. For instance, many of the teachers interviewed by Baran (2011) found that online courses required more time to prepare, design, and implement, and teachers were often undercompensated for this extra workload. In a case study of online university faculty, Neely and Tucker (2010) also concluded that a major downside to online education involved the lack of peer mentoring and pedagogical support. Chester's (2012) qualitative findings from interviewing online faculty members also claimed that inadequate technological training and support hindered a teacher's ability to effectively implement an online course. In addition, Shea's (2007) quantitative study of 386 online college instructors and Wickersham and McElhany's (2010) qualitative study of 447 institution department heads, deans, and faculty members added the lack of online teaching experience, poor online class interactions, excessive growth, and poor students preparedness and motivation to the growing list of factors that inhibit teachers from teaching online courses. Furthermore, some teachers become discouraged from teaching online due an unstable political climate at their schools and intellectual property issues (Baran, 2011; Wickersham & McElhany, 2010).

In an analysis of survey data from 210 undergraduate and graduate university students participating in hybrid courses, Mosca et al. (2010) found that these students struggled to have effective online discussions and interactions, maintain interest and motivation, and develop a sense of community within the online environment. Through a secondary analysis of college student data, Xu and Jaggars (2013a, 2013b) validated Mosca et al.'s findings and added that certain student populations (i.e. male, Black, and low-performing students) exhibited more difficulties with online learning than other populations. In a correlational study of 72 math students from an online high school, Kim et al. (2014) also discovered that many of these students struggled to overcome negative emotions associated with being forced to take online courses due to a lack of alternatives. However, in a quasi-experimental study of several Intermediate Algebra courses from a large private university, Spradlin (2009) claimed that these student struggles were not significantly different from those of students in traditional classes.

Best Practices

When determining the best practices for online learning programs, it is imperative to understand that there are diverse instructional strategies that can be implemented in an online format. These strategies may include the use of teacher designed learning modules made available within a specific Learning Management System (LMS) (Baran, 2011), video lectures and interactive PowerPoint presentations (Ernst, 2008; Mosca et al. 2010), online collaboration via discussion boards, live stream videos, and video chat tools (Doering & Veletsianos, 2008; Ernst, 2008), or online adaptive learning environments that provide students with video or animated instructions as well as opportunities to practice and demonstrate mastery of the learned content and skills (Foshee, 2013). While some studies in the research literature focused solely on one specific type of online learning strategy, many studies examined multiple online learning programs at once often to compare with face-to-face counterparts. With this diversity in mind, most of the online learning best practices mentioned in this section have been shown to work well with multiple types of online learning environment and strategies. However, some of the best practices may be more applicable to certain online learning strategies than others.

One prominent characteristic of successful online learning programs is an organized and well-structured online environment (Armstrong, 2011; Baran, 2011; Foshee, 2013; Jackson et al., 2010; Xu & Jaggars, 2013a). In a quantitative study of 1430 distance education students from a rural community college, Jackson et al. (2010) found that student satisfaction had a very strong correlation to clearly stated expectations, well-organized directions and activities, and a comfortable learning environment. These findings were further confirmed qualitatively in 2011 when Armstrong closely examined the experiences and perceptions of 16 undergraduate students at two universities in California. In Foshee's (2013) more recent quantitative study of 1970 remedial math students in Arizona, the organization and structure of the online learning environment was once again shown to significantly impact the academic performance of participating students. To maximize this academic success, the online learning environments should include reliable resources, easy-to-use tools to allow for effective interaction and discussion, research-based content and activities that promote active engagement, secure assessment guidelines, and clearly state goals and directions (Armstrong, 2011; Mosca et al., 2010; Jackson et al., 2010; Wickersham & McElhany, 2010; Kim et al., 2014). In an effort to achieve learning gains similar to those shown in the aforementioned research, the revised developmental math program examined in this study selected the iLearn Math online content delivery and assessment system, which has organized the content in manageable sized lessons grouped by chapter and then by unit. Each lesson consisted of animated, verbal, and text-based instruction, practice problems, a mastery exam, and additional review problems as needed. The sequencing of the content was designed so that each successive lesson topic built upon the topics from previous lessons.

In addition to an organized and structured learning environment, successful courses also tend to integrate a comprehensive technological and pedagogical support system and feedback mechanism for both students and teachers (Baran, 2011; Doering & Veletsianos, 2008; Ernst, 2008; Kaifi et al., 2009; Kim et al., 2014; Wickersham & McElhany, 2010; Yousef, 2012). Through a qualitative comparative analysis of interviews, focus groups, and class observations from 12 elementary school classrooms, Doering and Veletsiansos (2008) found that the most successful online courses strongly encouraged collaborations among teachers as well as support structures that promoted student interactions with each other and content experts. Kaifi et al.'s (2009) regression analysis of survey data from 203 undergraduate students also confirmed that the availability of adequate student support services was crucial for students to be successful even at the university level. In conjunction with these technological and pedagogical support systems, research also indicates that online student and teacher needs are best met through an online curriculum that is flexible and adaptable (Doering & Veletsianos, 2008; Kim et al., 2014; Mosca et al., 2010). The online content delivery and assessment used in the revised developmental math program examined in this study implemented technological and pedagogical support in the following ways: (1) immediate feedback after each practice problem indicating if the student was correct and showing them the correct answer, (2) access to each chapter and unit assessment results after the entire assessment was completed, (3) student access to a review mode that allowed them to revisit any previous content that they had already mastered, and (4) student and teacher access to technical support via email or phone at any time. The online content delivery system also provided students with a more personalized, adaptable learning experience by allowing them to skip content based on the results of unit, chapter, and lesson challenge exams and by providing additional practice and review exercises based upon the students' performance on previous problems and exams.

Once a well-organized online environment is in place, the teacher is then responsible for guiding, monitoring, and managing student learning within that environment in order to ensure quality interactions and identify and address issues promptly as they arise (Baran, 2011; Bressler et al., 2010; Chester, 2012; Kim et al., 2014; Xu & Jaggars, 2013a). Through a quantitative correlational study of 219 accounting students from a Texas university, Bressler et al. (2010) concluded that confidence and self-efficacy issues of students need to be recognized and remedied early in the course because of the impact that these affective attributes have on student performance and success. As confirmation of Bressler et al.'s (2010) findings, Kim et al. (2014) also discovered that motivation was strongly correlated to both self-efficacy and achievement. One of the best ways to motivate and engage students throughout an online course is through clear and regular student-student and student-teacher communication (Armstrong, 2011; Baran, 2011; Wickersham & McElhany, 2010; Yousef, 2012). However, in a comparative analysis of survey data from 88 online education students at a California university, Yousef (2012) found that the level of communication needed varied with the age and maturity of the participating students. In order to further motivate and engage students, online teachers should also be enthusiastic, willing to explore and develop online content, regularly accessible to students, and timely in providing feedback and guidance (Baran, 2011; Ernst, 2008; Jackson et al., 2010; Yousef, 2012). In the revised developmental math program examined in this study, online student-student and student-teacher interactions were encouraged via the discussion board or the interactive conferencing and virtual white board tools (all features of the school's Learning Management System). In addition, emails were also a means for teacher-student interactions.

Research Needs

In spite of the large quantity of both qualitative and quantitative research pertaining to the benefits and challenges of online learning for science, technology, engineering, and math, Kim et al. (2014) and Paadre (2011) were the only ones to conduct studies that explored the impact of online coursework on the learning and performance of math students in particular. In addition, only Jackson et al. (2010) and Xu and Jaggar (2013a, 2013b) targeted students from two-year community colleges. Thus, further research is needed to determine the impact of online education on math students enrolled in two-year community colleges.

Mastery Learning

Building upon the ideas of early progressives like Carlton Washburn and Henry Morrison and of behaviorism from the 1960's, mastery learning began to take formal shape under the influence of Bloom (1976) and Carroll (1963). According to Slavin (1987), Block and Anderson (1975), and Bloom, mastery learning refers to instructional methodologies which utilize feedback, assessments, and instruction to enable students to achieve a set level of mastery for specific skills and concepts. These levels of mastery can be uniformly achieved by students if they put in the requisite time and effort and have sufficient resources to do so (Bloom, 1976; Carroll, 1963; Slavin, 1987). As with online learning, a large proportion of studies in recent educational research literature have focused on the efficacy of mastery learning within face-to-face and online classroom settings. Even though some of this mastery learning research has shown improvements in academic performance and attitude of students (Abakpa & Iji, 2011; Guskey, 2007; Hoon et al., 2010), other research studies have concluded that some students have associated negative feelings (i.e. anxiety, stress, and frustration) with mastery learning as well (Frick et al., 2011). This section examines the benefits, challenges, and best practices of mastery learning based on this recent research literature. Then the gaps in this literature and the specific needs for additional research are identified.

Benefits

A major objective of mastery-based learning is to help a vast majority of students achieve the learning objectives in a uniform manner (Block, 1980). Mastery learning curricula often incorporate individualized instruction which allows the student to progress in the content at their own pace (Block, 1980; Furner & Gonzalez-Dehass, 2011). As Furner and Gonzalez-Dehass (2011) carefully synthesized available literature pertaining to the underlying causes of math anxiety, they found that this mastery approach to learning often reduced or prevented math anxiety in participating students. Abackpa and Iji (2011), Changeiywo et al. (2011), Hoon et al. (2010), Toheed and Ali (2011), and Miles (2010) also found that the implementation of mastery learning strategies increase academic achievement for students at the elementary, middle, and high school levels. Hoon et al.'s (2010) quasi-experimental study on the effect of mastery learning on the performance of 262 secondary students and Rowe's (2010) quasi-experimental evaluation of the effect of mastery learning on 226 community college students both concluded that mastery learning increased student engagement and motivation as well. Furthermore, based on a quantitative study of pretest and posttest scores from 62 sixth grade remedial math students, Lin et al. (2013) also found that different mastery learning strategies influenced the academic achievement of participating students at different levels. More specifically, students participating in a game-based mastery learning activity performed significantly better (by 8% on the posttest with $p < .05$) than those who participated in a video-based mastery learning activity.

In an effort to find additional benefits for mastery learning, Athens (2011) analyzed records of time engaged class activities, surveys, and test results for 24 honors physics students at a private high school in Fort Meyers, Florida. Athens found that additional benefits for mastery learning included added emphasis on deep learning and understanding and improved time management skills for the participating students. Furthermore, mastery learning helped students focus on filling their individual knowledge gaps without the added pressures of constantly comparing their progress to that of their classmates (Abakpa & Iji, 2011; Athens, 2011). Literature reviews by Furner and Gonzalez-DeHass (2011) and Guskey (2007) also identified other advantages of mastery learning which included increased student confidence, improved attendance, and a greater likelihood for students to view failures and mistakes as stepping stones to achieving excellence without the negative emotions and attitudes that are often associated with failure and mistakes in school.

Challenges

Although some researchers have found student attitudes to improve when actively participating in a mastery learning curriculum (Abakpa & Iji, 2011; Guskey, 2007; Hoon et al., 2010), other research has noted elevated stress and anxiety in some of these students (Frick et al., 2011). Through a quantitative analysis of perceived stress questionnaires from 204 Doctor of Pharmacy students, Frick et al. (2011) concluded that the stress and anxiety that resulted from mastery learning can inhibit student performance and even negatively impact their overall health (Frick et al., 2011). Much of the added stress and anxiety noted in Frick et al.'s (2011) study was due to increased time constraints in which students had to complete their work. Thus, allowing students sufficient time to master concepts is a critical ingredient to overcoming these issues of stress and anxiety for students (Block, 1980; Guskey, 2007). Additional challenges with mastery approaches to learning include poor teacher training, increased time investment and workload for teachers, inadequate student and teacher support, irrelevant content, and ineffective assessment strategies (Block, 1980; Furner & Gonzalez-DeHass, 2011; Guskey, 2007).

Best Practices

When determining the best practices for mastery learning programs, it is imperative to understand that, as was the case with online learning, there are diverse instructional strategies that can be implemented in the name of mastery learning. These strategies may include the use of online applications (i.e. Google Apps, email, chat, videos, and webpages) to provide students with the means to navigate the curriculum in a self-paced manner (Athens, 2011), the use of guided teacher manuals and lesson plans to aid teachers in the implementations of mastery learning in the classroom (Abackpa & Iji, 2011; Changeiywo et al., 2011; Wambugu & Changeiywo, 2008), and the integration of a small units or activities that focus on students' mastery of specific concepts (Lin et al., 2013; Toheed & Ali, 2011). Furthermore, Lin et al. (2013) also found that different mastery learning approaches have different effects on student learning. With this diversity in mind, most of the mastery learning best practices mentioned in this section have been shown to work well with multiple types of mastery learning strategies. However, some of the best practices may be more applicable to certain mastery learning strategies than others.

The first crucial element of a successful mastery-based learning course is a well-organized curriculum that encourages active knowledge construction, collaboration, and creative thinking and problem-solving (Block, 1980; Furner & Gonzalez-DeHass, 2011). In addition, this curriculum should include content that is relevant, appropriate, and properly aligned to set standards and research (Furner & Gonzalez-DeHass, 2011; Guskey, 2007). Once the curriculum is designed and ready for implementation, the next important step is to ensure that the teacher is properly trained to effectively manage and guide student learning during the class (Block, 1980). This training should aid the teacher in providing individualized instruction and support to the students and in addressing a variety of learning styles in order to meet student needs (Block, 1980; Furner & Gonzalez-DeHass, 2011). Regular, constructive feedback is also important so that students can learn effectively and efficiently (Athens, 2011; Guskey, 2007). Additional elements of a successful master-based learning course include providing sufficient time for students to master concepts, emphasizing success through failure, and providing alternative resources and adequate support for students (Block, 1980; Furner & Gonzalez-DeHass, 2011).

With the aforementioned best practices in mind, the revised developmental math program examined in this study implemented mastery learning strategies via the online content delivery system. This online, mastery-based learning system was designed to help students fill gaps in their mathematical knowledge and actively learn new concepts and skills (Collins, n.d.). The content was organized in manageable sized lessons that were sequenced so that each lesson built upon the content and skills learned in previous lessons. Through practice problems and mastery exams, students demonstrated their mastery of a topic before moving on to the next topic. Each element of the content delivery system (i.e. content sequencing and scaffolding, instruction, feedback, etc.) was developed based on education research which focused on general instructional best practices, instructional strategies for teaching at-risk and learning disabled students, and multimedia delivery of instruction (iLearn, n.d.). To further help teachers effectively monitor student progress and offer focused, individualized support, the participating math department also conducted several training meetings for participating instructors to demonstrate the effective use of the online content delivery system, including its many reporting and feedback features. Students were also provided with regular teacher and tutor support and feedback during each class session.

Research Needs

Even though the current research on mastery learning was conducted with students from a variety of grade levels, Rowe (2010) was the only one to study the impact of mastery-based learning specifically on community college students. Furthermore, Hoon et al. (2010) and Toheed and Ali (2011) were the only researchers to focus their studies specifically on math students. Thus, further research is necessary to address the impact of mastery learning for math students within a community college setting. In light of the seemingly contradictory findings of Rowe (2010) and Guskey (2007) who saw an increase in student engagement and motivation compared with Frick et al. (2011) who saw an increase in student stress and anxiety, there is also a need for additional research that seeks to determine the conditions and factors that promote positive or negative attitudes within a mastery-based learning setting. Last, since almost all of the recent research on mastery learning has been quantitative in nature, there is also a need for additional qualitative research to gain a more vibrant, holistic perspective of the impact of mastery learning on student attitude and achievement.

Project-Based Learning

Philosophers and teachers have been applying the principles of active and experiential learning (foundational strategies often associated with project-based learning) for centuries (Graaf & Kolmos, 2007). In the early 1900's, John Dewey and William Kilpatrick both played significant roles in promoting the use of project-based learning as they asserted the need for students to build meaningful connections to knowledge through active, experiential activities (Dewey, 1916; Kilpatrick, 1921; Levine, 2001). Today project-based learning has continued to impact student learning as it has been integrated with curriculum at many schools. Though multiple definitions of project-based learning exist, the definition adopted for the current study is a learning approach which centers the learning experiences of students around engaging activities and problems designed to give context to content (Graaff & Kolmos, 2007).

Several studies have shown that project-based learning improved student learning, satisfaction, engagement, and attitude (Bedard, Lison, Dalle, Cote, & Boutin, 2012; Foutz et al., 2011; Tseng, Chang, Lou, & Chen, 2013; Whitlock, 2013). However, research has also found that challenges with student motivation, time and content management, and assessment may impede the success of project-based learning curricula (Lee, 2010; Rogers, Cross, Gresalfi, Trauth-Nare, & Buck., 2011; Whitlock, 2013). This section examines the benefits, challenges, and best practices of project-based learning based on this recent research literature. Then the gaps in this literature and the specific needs for additional research are identified.

Benefits

In a mixed methods study of middle school teachers who participated in a five-day project-based and problem-based learning workshop in Georgia, Foutz et al. (2012) found that improved student performance and understanding were key benefits of project-based learning. This benefit was also confirmed by Eskrootchi and Oskrochi (2010), Kanter and Konstantopoulos (2010), and Whitlock (2013). According to Foutz et al. (2012), additional benefits of project-based learning also include an emphasis on active experiential problem solving within real-world, increased exposure to cross-curricular content and applications, and increased student engagement and satisfaction. In a quantitative examination of the efficacy of project-based curricula on 480 undergraduate students from a university in Canada, Bedard et al. (2012) confirmed many of Foutz el al.'s (2012) conclusions and also added increased self-confidence and self-efficacy to the list of benefits. In addition, Movahedzadeh et al.'s (2012) quantitative study of 12 participating molecular biology students from Chicago and Swan's (2011) phenomenological study of female engineering students and their college instructors both concluded that project-based learning also increased the students' interest in the discipline being studied. According to Mioduser and Betzer (2008) quantitative study of 120 high school students and Rogers et al.'s (2011) study, another key advantage of project-based learning is that it facilitates more holistic knowledge construction. In addition, studies have also shown that many project-based learning programs improved student attitude as well as increased opportunities for creative thinking and collaboration (Mioduser & Betzer, 2008; Tseng et al., 2013; Verma, Dickerson, & McKinney, 2011).

Challenges

In a qualitative case study that examined two technical high school teachers in Indiana, Lee (2010) discovered that one of the biggest challenges with project-based learning is to design the curriculum so that sufficient content is covered while still providing students with opportunities to more deeply examine key concepts and engage in quality problem-solving experiences (Lee, 2010). In a similar qualitative study that backed up Lee's (2010) findings, Rogers et al. (2011) also found time and classroom management when implementing a project-based curriculum can also be quite problematic for teachers accustomed to the more structured traditional classroom. Many teachers also struggle to keep students actively engaged in the projects, especially since many students have minimal prior experience with this style of learning and struggle to adapt (Lee, 2010; Rogers et al., 2011). In light of the interactive and collaborative nature of many projects, effectively assessing student learning and contributions can also be a big challenge (Rogers et al., 2011).

Best Practices

As is the case with online and mastery-based learning strategies, there are also diverse instructional strategies that can be implemented in the name of project-based learning. These strategies may include the use of cross-curricular units that utilize lectures and hands-on learning activities (Kanter & Konstantopoulos, 2010; Lee, 2010), the use of Webquests and internet resources (Grant, 2011), or the use of computer simulation modeling and experiential learning to active construct knowledge (Eskrootchi & Oskrochi, 2010). With this diversity in mind, most of the project-based learning best practices mentioned in this section have been shown to work well with multiple types of project-based learning strategies. However, some of the best practices may be more applicable to certain project-based learning strategies than others.

Teachers of project-based learning courses need to be adequately trained and mentored so that they can best design, implement, and manage their classes with research- and standards-based teaching philosophies and strategies (Lee, 2010). The activities and projects should also involve active, inquiry-based problem-solving in real-world contexts and should integrate collaborative and reflexive elements that motivate and engage students in fun and creative ways (Bedard et al., 2012; Grant, 2011; Kanter & Konstantopoulos, 2010). Furthermore, a strong support system should be put in place in order to help students adjust to a project-based learning environment, manage the stress often associated with unfamiliar approaches to learning, effectively manage their time, and guide group collaborations (Bedard et al., 2012; Rogers et al., 2011).

With the aforementioned best practices in mind, the revised developmental math program examined in this study implemented project-based learning strategies through weekly projects and activities. These projects and activities were selected in order to give students further practice with learned concepts and additional experience in applying mathematics within real-world contexts. To further assist in the effective implementation of these projects, the participating math department also conducted several project design and training meetings for participating instructors to compile a database of potential projects and activities and demonstrate how to use them in the classroom.

Research Needs

Although the recent research on project-based learning has studied student populations from a variety of grade levels using quantitative, qualitative, and mixed methods approaches, Movahedzadeh et al. (2012) conducted the only study that focused specifically on students from a community college. Furthermore, Lee's (2010) study was the only one that specifically targeted mathematics education although the participants were teachers rather than students. Therefore, more research must be conducted that examines the influence of project-based curricula on math students within a community college setting.

Mixed Approaches to Learning

The previously mentioned research on online, mastery, and project-based learning indicates that each of these approaches are most effective within a well-organized curriculum designed to promote effective interactions and collaborations and to offer a flexible and adaptable pathway for each individual student to succeed (Armstrong, 2011; Athens, 2011; Baran, 2011; Block, 1980; Doering & Veletsianos, 2008; Kim et al., 2014; Mosca et al., 2010; Verma et al., 2011). In addition, these approaches tend to most positively influence student success when strong support structures and reliable communication mechanisms are in place and used regularly (Armstrong, 2011; Baran, 2011; Block, 1980; Doering & Veletsianos, 2008; Guskey, 2007; Kaifi et al., 2009; Kim et al., 2014; Lee, 2010; Wickersham & McElhany, 2010; Yousef, 2012). However, many challenges arise with each learning approach which may be remedied if used in tandem with the others. For instance, students often struggle to interact effectively and build a sense of community within an online learning environment (Mosca et al., 2010). Including a project-based component in addition to the online elements of a course could help overcome this challenge by providing students with increased opportunities to actively collaborate in innovative and creative ways (Verma et al., 2011). Furthermore, the negative attitudes often associated with online education can also be remedied with the inclusion of mastery and project-based learning components that have been shown to improve student motivation, confidence, and engagement (Bedard et al., 2012; Foutz et al., 2011; Guskey, 2007; Kim et al., 2014; Mioduser & Betzer, 2008; Mosca et al., 2010; Rowe, 2010; Tseng et al., 2013). An adaptive online content delivery and assessment system could also relieve mastery-learning teachers of the often overwhelming need to customize the learning experience for each individual student (Athens, 2011; Doering & Veletsianos, 2008; Kim et al., 2014; Mosca et al., 2010). A mix of adaptive online content assessment with both summative and formative assessments of project contributions could also help to alleviate the assessment challenges of mastery and project-based learning, providing a more holistic view of student learning (Frick et al., 2011; Rogers et al., 2011).

In addition, the integration of these three learning approaches is further justified as each tends to address a different aspect of the learning solution. More specifically, online learning focuses on the content delivery platform (Anderson, 2008), mastery learning focuses on the organization and management of the curriculum, time, and resources (Athens, 2011; Block, 1980; Saettler, 2004), and project-based learning focuses on the active application of acquired knowledge and skills through problem-solving in context (Bedard et al., 2012). Thus, the online delivery of a well-organized mastery-based curriculum complemented by contextualized projects is one way to create a complete learning solution for students.

While the revised developmental math courses at the participating college utilized an online, mastery, and project-based learning solution, the traditional courses were taught using a traditional style for content delivery (Hendricks, 2012; Spradlin, 2009). Teachers of these traditional courses would use predominantly direct instruction techniques during class to teach students about the mathematical concepts. These courses would typically present mathematical content in the order presented in the course textbook. Students would be assigned homework for each textbook section, and at the end of 1 or 2 chapters, an exam would be administered. The course final exam given to students at the end of each semester was the same for all revised and traditional courses of the same level.

Analysis of Methodologies

When the participating college opted to implement their new developmental math program in 2012, a three year evaluation plan was also put into place which included the collection of student achievement, attitude, and demographic data. While the new program evaluation relied heavily upon these collected data, the data analyses provided only a snapshot of the program's effectiveness. In order to glean even deeper insight into the new program, this study more fully analyzed these archived data. As the archived data for the quantitative portion of this study involved pre-existing groups over which the researcher had no control, a quasi-experimental nonequivalent control group design was a logical design choice (Campbell & Stanley, 1963). Though some other professionals and researchers refer to such a design alternatively as causal-comparative and nonexperimental, the overarching purpose of the design is to further study nonmanipulable independent variables that often exist within education settings (Fraenkel & Wallen, 2000; Johnson, 2001). While these research designs may employ statistical tests similar to those used in true experimental designs, the inability of the researcher to manipulate the independent variables does limit internal validity of the study (Gall, Borg, & Gall, 1996; Schenker & Rumrill, 2004). Conversely, Schenker and Rumrill (2004) noted that external validity could be strong in such a study as long as a sample is used which is representative of the target population.

This quasi-experimental nonequivalent control group design used a multiple regression analysis to determine how much the instruction methodology (revised or traditional), initial attitude, initial content knowledge, instructor, course level (PreAlgebra, Beginning Algebra, Intermediate Algebra), student gender, and student ethnicity influenced the final attitude and acquired content knowledge of students in the developmental mathematics program of the participating community college. The inclusion of the instruction methodology variables was critical to determine if methodology significantly impacted a student's final math attitude and academic achievement in the developmental mathematics program. Weiner's (1985) theory of attribution provided the justification for using the attitude and content knowledge variables. In addition, the inclusion of the instructor and course level variables helped determine if significant relationships existed between instructors or the level of math content being taught and the final content knowledge. As some studies found gender to have a significant impact on student attitude and achievement (Arslan et al., 2012) while others found that gender had no impact on the attitude and achievement (Dueatepe-Paksu & Ubuz, 2009), gender was included in the regression analysis as well in order to determine if it was related to the attitudes and achievements of students in the context of the developmental math program examined in this study. As Kaifi et al.'s (2009) study was the only one to examine the effects of ethnicity on computer usage and online course participation, the use of ethnicity as another independent variable for this regression analysis was also justified to provide additional insight into the relationship between it and the final attitude and academic achievement of participating students.

The research literature includes several studies that have analyzed archived data in order to shed light on important research questions in the field of education. For example, Paadre (2011) studied the math proficiency of ninth grade vocational school students were impacted by online mathematics. An ANCOVA (analysis of covariance) was used in this study to determine if students from the online and the hybrid summer school programs performed differently on the Spring and Fall 2010 NWEA (Northwest Evaluation Association) tests. In order to determine the degree with which at-risk reading students were influenced by electronic educational technology, Harris (2010) compared the archived reading scores of the treatment and control groups using an ANOVA (analysis of variance). In a similar manner, Pope (2013) compared the success rates of students in traditional and online courses, using an independent sample *t* test on archived COMPASS test. Williams (2013) also used a *t* test on archived California Achievement Test scores to see if student achievement changed significantly after a supplemental education service. In order to determine what faculty actions influenced distance education students satisfaction, Jackson et al. (2010) utilized a multiple regression analysis on archived survey data from two community colleges. Using studies like these as a guide for analyzing archived data, this study used a multiple regression analysis to determine how instruction methodology (revised or traditional), initial attitude, initial content knowledge, instructor, course level (PreAlgebra, Beginning

Algebra, Intermediate Algebra), student gender, and student ethnicity interacted with the final attitude and academic achievement of participating developmental math students.

Due to the limitations inherent with a quasi-experimental nonequivalent control group design, this study also incorporated a qualitative component to give added context to the quantitative results and further pinpoint specific aspects of the program that helped or hindered student success. Cordes (2014), Armstrong (2011), and Grant (2011) each conducted studies which helped to inform this qualitative component of the current study. Cordes' (2014) study which utilized interviews to determine the experiences and perceptions of 13 students who failed postsecondary developmental mathematics. Armstrong (2011) also used interviews to determine key factors that influenced the success of 16 undergraduate students taking online courses. Focusing on the influence of project-based learning at the eighth grade, Grant (2011) used interviews with a sample of 5 students. The aforementioned qualitative research studies suggest that 5 to 16 students is a reasonable sample size to gain good insight into the research questions. In addition, the use of one-on-one interviews with the participating students seems to be an important method for gathering the requisite qualitative data.

Much of the research literature also provides strong justification for the use of both quantitative and qualitative methods in a single study to add strength and insight to the study's conclusions. For example, Swift (2012) selected a mixed methods design to explore the influence of cooperative learning methods on 500 preservice education teachers, asserting that the results were enriched beyond what the quantitative and qualitative designs could have achieved alone. Swift utilized quantitative analyses on math attitude and academic test scores and qualitative interviews as key data sources in the study. Duatepe-Paksu and Ubuz (2009) also elected to use a mixed methods design that used a MANCOVA (multi-variate analysis of variance) on student achievement and attitude assessment scores in conjunction with interviews of 13 students to determine the impact of drama-based geometry instruction. In an effort to determine the effectiveness of a workshop that emphasized the integration of math, science, engineering, and agriculture, Foutz et al. (2011) also implemented a mixed methods study that examined pretest and posttest scores as well as informal conversations with the middle school teachers who participated in the study. In addition to the literature that supports this design choice, the use of a mixed methods study also helps build up the sparse body of qualitative research pertaining to the topics of math attitude and achievement and mastery learning.

Summary

In light of the issues of attrition, negative attitude, and poor achievement within many of the existing traditional developmental math programs, many colleges are making significant revisions to their programs (Ashby et al., 2011; Bailey et al., 2009; Boatman, 2012; Kirst & Bracco, 2004). Improving student attitude and achievement have been two major emphases of these revisions. However, there is a shortage of research that explores the connections between attitude and achievement at the community college levels. The body of literature also indicates that online, mastery, and project-based learning approaches have been incorporated in many of these revised developmental math programs. Although these three approaches to learning have been shown to improve student achievement or attitude (Abakpa & Iji, 2011; Foutz et al., 2011; Guskey, 2007; Mioduser & Betzer, 2008; Shih et al., 2012; Tseng et al., 2013), various research studies have also shown that each of these approaches (when used separately) have also induced negative feelings and decreased motivation in students (Frick et al., 2011; Kim et al., 2014; Lee, 2010; Mosca et al., 2010). Therefore, further research is required to more clearly pinpoint the reasons for these complex and often contradictory results, especially within a community college setting. Furthermore, more research must be conducted which explores the efficacy of a single program that integrates online, mastery, and project-based learning. When used in tandem, these three approaches may minimize their individual challenges while maximizing their benefits on student achievement and attitude.

The present study helped to fill these research needs by examining how much of the variance in the final math attitude and content knowledge of developmental math students can be explained by instruction methodology (revised or traditional), initial attitude, initial content knowledge, instructor, course level (PreAlgebra, Beginning Algebra, Intermediate Algebra), gender, and ethnicity. In addition, this study's mixed methods design (a quasi-experimental nonequivalent control group component and a qualitative component) was supported by the existing literature and provided a vivid and holistic view of student learning and attitude within the developmental math program being studied (Swift, 2012).

Chapter 3: Research Method

The purpose for conducting this mixed methods case study was to discover how a revised developmental math program that integrates online, mastery, and project-based learning has impacted student achievement and attitude compared with a traditional lecture-based curriculum taught at a rural community college. By combining a quantitative analysis of archived student achievement, attitude, and other course-related and demographic data with a qualitative analysis of student interviews, this study contributed to the research literature by offering critical insights regarding the efficacy of the revised program and identified key program elements that drive or hinder student success. This chapter more thoroughly describes this study's mixed methods design, including a rationale for its selection. In addition, my role as researcher is explained along with methods used to minimize researcher bias and address potential ethical issues. A more in-depth explanation of the setting, participants, instrumentation, recruitment procedures, and data collection and analysis strategies is also provided. At the conclusion of the chapter, issues of validity and trustworthiness are presented along with measures taken to minimize these issues.

Study Setting

In the Fall of 2012, the participating community college began its implementation of a revised developmental math program that incorporated multiple learning approaches (i.e. online, mastery, and project-based learning) to improve student achievement and attitude towards mathematics. For the next 3 years, the college compiled a database of student achievement, attitude, and demographic data for the purpose of evaluating the revised program's effectiveness as part of the college's standard instructional practice. As there is not yet any research on a developmental math program with this unique combination of learning approaches, conducting this mixed methods study at the participating community college is imperative.

The participating college has an annual enrollment of about 4600 students. As shown in Figure 1, the student population has a racial makeup that is approximately 85% White Caucasian, 4% Hispanic, and 11% from other races. The student population is also 56% females and 44% males, 65% full-time and 35% part-time, 92% state residents and 8% non-residents, and 60% freshmen. The college is open enrollment and offers predominantly one- or two- year Associates degrees and certificates.

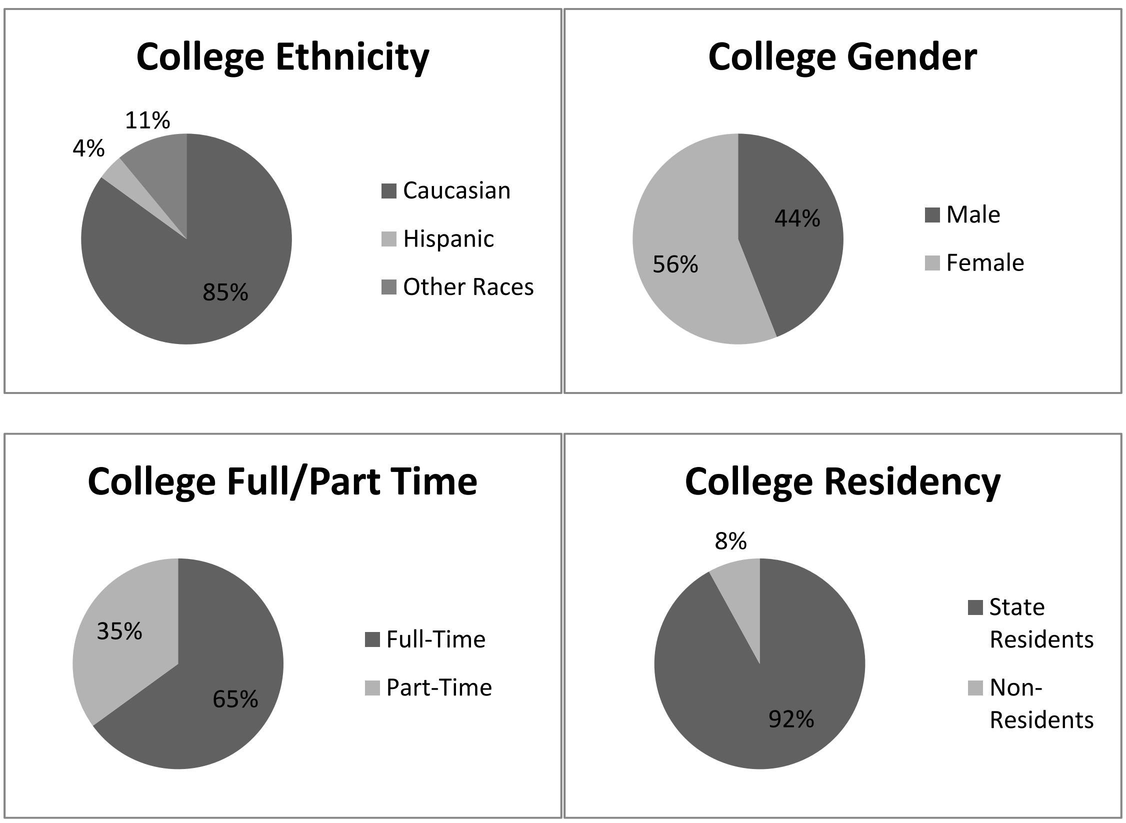

Figure 1. Participating college demographics.

The participating community college is situated within a rural city in the Western United States. The city has a population of approximately 6200 people. As shown in Figure 2, the 2010 Census indicated that the city's population has a racial makeup that is approximately 84.5% White Caucasian, 9.7% Hispanic, and 5.8% from other races. The females in the city make up 53.2% of the population while 46.8% of the population is male.

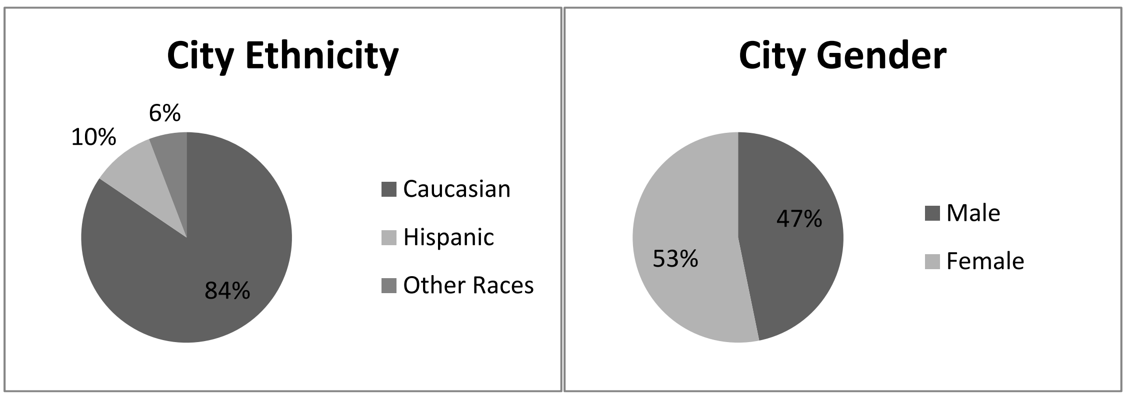

Figure 2. City demographics

Key players in the creation, implementation, and evaluation of the participating college's revised developmental mathematics program included the contributing math department faculty members and the students. In addition to the math faculty members and the students, the college President, Vice President of Academic Affairs, and the college's Institutional Review Board all provided critical support for the implementation and evaluation of the revised developmental math program. For this study, these same stakeholders also had a major impact by granting access to the archived developmental math program data, approving and aiding in the selection of participating students to be interviewed, and offering additional information and insight regarding the program development, instrumentation, data collection, and analysis procedures.

Research Design and Rationale

The mixed methods research design in this study was used to analyze archived student achievement, attitude, and other course-related and demographic data in conjunction with student interviews to examine the influence of the revised developmental mathematics program at the participating community college. This section begins by restating the research questions and the central phenomenon being studied. Then the strategies used for collecting and analyzing the qualitative and quantitative data are presented along with a rationale for using both methods to best address the research questions.

Research Question 1

How does the final student content knowledge in revised developmental mathematics courses (integrating online, mastery, and project-based learning) compare with that of students in traditional developmental mathematics courses at one community college in the Western United States?

H_0: The final student content knowledge in revised developmental mathematics courses (integrating online, mastery, and project-based learning) is not significantly different from that of students in traditional developmental mathematics courses at one community college in the Western United States.

H_1: The final student content knowledge in revised developmental mathematics courses (integrating online, mastery, and project-based learning) is significantly different from that of students in traditional developmental mathematics courses at one community college in the Western United States.

Research Question 2

How does the final student attitude towards mathematics in revised developmental mathematics courses (integrating online, mastery, and project-based learning) compare with that of students in traditional developmental mathematics courses at one community college in the Western United States?

H_0: The final student attitude towards mathematics in revised developmental mathematics courses (integrating online, mastery, and project-based learning) is not significantly different from that of students in traditional developmental mathematics courses at one community college in the Western United States.

H_1: The final student attitude towards mathematics in revised developmental mathematics courses (integrating online, mastery, and project-based learning) is significantly different from that of students in traditional developmental mathematics courses at one community college in the Western United States.

Research Question 3

How do students describe their experiences, attitudes, and content knowledge acquisition while participating in the revised and the traditional developmental mathematics programs at one community college in the Western United States?

Quantitative Data Collection and Analysis

The quantitative portion of this mixed methods study utilized the archived student achievement, attitude, and other course-related and demographic data gathered by the participating community college for the purpose of evaluating their revised developmental mathematics program. These data were analyzed using a quasi-experimental nonequivalent control group design. This quantitative design is most appropriate when studying nonmanipulable independent variables which are often prevalent within education settings (Campbell & Stanley, 1963; Fraenkel & Wallen, 2000; Johnson, 2001). Although this quantitative approach may utilize the same statistical tests used in true experiments, the researcher's inability to manipulate the independent variable limits the internal validity of the study (Gall et al., 1996; Schenker & Rumrill, 2004). Nevertheless, if the target population is adequately represented by the participant sample, the external validity of the design can still remain strong (Schenker & Rumrill, 2004). With previous research as a guide (Harris, 2010; Jackson et al., 2010; Paadre, 2011; Pope, 2013; Williams, 2013), a multiple regression analysis was used to determine how much instruction methodology, initial attitude, initial content knowledge, instructor, course level (PreAlgebra, Beginning Algebra, Intermediate Algebra), student gender, and student ethnicity influenced the final attitude and academic achievement of participating developmental math students. The instruction methodology, attitude, and content knowledge variables were included in the analysis in order to fully address research questions 1 and 2 and tie the results to the theoretical framework. The remaining variables (i.e. instructor, course level, gender, and ethnicity) were included to account for moderating effects on the dependent variables. The Purpose of the Study section of Chapter 1 contains a complete rationale for including each of these variables.

Qualitative Data Collection and Analysis

The qualitative analysis for this mixed methods case study examined student experiences (via one-on-one interviews) in the developmental mathematics program at the participating college. In order to minimize issues with student recollection of their developmental math experiences and ensure the participation of students who completed their developmental math program during the initial program evaluation timeframe (i.e. Fall 2012 to Spring 2015), interviewees were selected from Spring 2015. In an effort to focus on students who completed all of their developmental mathematics coursework in the Spring 2015 (the last semester in which the developmental math program evaluation data was collected), only students who finished their last developmental math course (Intermediate Algebra) during that semester were used. In order to ensure that students in both the revised and traditional developmental math courses were represented in the interview phase of this study, these students were first divided into two groups based on the instruction methodology (revised or traditional) used in their course from Spring 2015.

Next, from each of these two groups, three subgroups were formed based on the students' level of academic performance. Performance levels were defined as follows: (a) students who performed exceptionally well (did not repeat any developmental math courses and received an A in each developmental math course taken); (b) students who performed at an average level (did not repeat any developmental math courses and received mainly C's in each developmental math course taken); and (c) students who demonstrated significant struggles with the developmental math coursework (needed to repeated developmental math courses and received a C- or lower in at least two of those courses). The performance levels were chosen in this manner so that the groups reflected the entire developmental mathematics experiences of students rather than just their experiences for a single semester course. Thus, six groups of students were created (three performance level groups for students in the revised program and three performance level groups for students in the traditional program). A list of students from each of these six groups was made. As my version of the database had all identifiable information removed from it, I then requested student contact information (i.e. name, email, and phone number) from the college agent who de-identified the original archived data. Contact information was only requested for the students who qualified as potential interviewees.

Upon receipt of the aforementioned student contact information, I contacted students in the order listed via email or phone to request their participation in an interview until two students from each group agreed to participate. Those that agreed to participate were asked to sign an interview consent form prior to their participation. Once the interview consent forms were signed and returned to me, I interviewed the participating students. I then transcribed and coded the interviews. Next, I organized the codes into categories and analyzed them to find emergent themes. This thematic coding analysis provided insight into the similarities and differences among students participating in the revised and traditional programs. In addition to addressing the third research question, this qualitative analysis also provided additional support for the quantitative findings and identified key components of the revised program that positively or negatively impacted student achievement and attitude.

In an effort to ensure the qualitative validity of the coding and thematic analysis, I clarified any researcher bias that has likely influenced the interpretation and approach used in the study, carefully analyzed negative cases that arise, used member checking by allowing interviewed participants to review the interpretations and findings from their interviews, and used thorough, rich descriptions of the participants, settings, and procedures of the study (Creswell, 2013).

Rationale for Mixed Methods Design

For this study the qualitative and quantitative data analysis equally contributed to answering research questions one and two, which compare the final attitude and content knowledge between students in the traditional and revised developmental math courses at the participating college. In addition, the qualitative analysis answered the third research question (How do students describe their experiences, attitudes, and content knowledge acquisition while participating in the revised and the traditional developmental mathematics programs?). By analyzing the experiences of the participating students, specific factors were identified that further explained the results of the quantitative analysis. Due to the equal prioritization of the quantitative and qualitative data and analyses for this study, a convergent parallel mixed methods design was used (Creswell & Plano Clark, 2010; Laureate Education, 2010). Using this design, both data types were analyzed simultaneously but independently of each other (Creswell & Plano Clark, 2010). After the quantitative multiple regression analysis and the thematic analysis of the qualitative interview data were completed, these results were then integrated to make meta-inferences and provide a more thorough explanation of how the developmental math program at the participating college influenced student content knowledge acquisition and attitude towards mathematics (Swift, 2012; Teddlie & Tashakkori, 2009).

Role of the Researcher

During the first 3 years of implementation of the revised developmental math program, I served as one of the developmental math instructors at the participating college. In addition, I was in charge of compiling the data from all of the developmental and general education math courses during that time. For this study, I managed and analyzed the data collected during those first 3 years of program implementation. The use of data already archived by the participating college minimized potential bias towards students that I know and have taught. To further minimize the potential for researcher bias for the quantitative portion of this study, personal data that could point to the identity of participating students and teachers were stripped from the archived data before it was entrusted to me for use in this study. Thus, complete anonymity was retained for all students and teachers during the quantitative analysis. However, I did obtain contact information for the potential interviewees for the qualitative phase of this study. Therefore, in order to protect and minimize risk to these students, this study did not include any identifiable information for these students either in their interview transcripts or when referring to their interviews. In addition, pseudonyms were used when referencing specific interviewees. Furthermore, most of the interviewees had finished their coursework at the participating community college due to the fact that the interviews took place approximately 2 years after the students completed their developmental math program. Thus, I was not able to influence past, present, or future grades of these students.

I used computer software (i.e. Microsoft Excel, SPSS) to find the student enrollment in the traditional and revised developmental math programs for each semester from Fall 2012 to Spring 2015, the total number of developmental math courses taken for each student, and additional descriptive statistics and graphics from the original data as needed. Next, I ran a multiple regression analysis to determine how instruction methodology, initial attitude, initial content knowledge, instructor, course level (PreAlgebra, Beginning Algebra, Intermediate Algebra), student gender, and student ethnicity interacted with the final attitude and academic achievement of participating developmental math students. Then within the NVivo software, I used matrix coding, word frequency queries, and code queries on the interview transcripts to develop the initial node structure and identify overarching themes in the qualitative data. Microsoft Excel was also used to help with the thematic analysis. In addition, I stored all digital files (including the original data files, files generated from that data, and backup files) on a flash drive and two different desktop computers.

For the qualitative portion of this study, I selected and contacted students who participated in either the revised or the traditional developmental mathematics programs. More details about the participant selection logic and procedure can be found in the following "Methodology" section. Next, I interviewed these students and coded the interview transcriptions in order to paint a more vivid picture of their experiences in their developmental mathematics courses. In order to minimize bias and maximize the protections for participating students, students were selected and interviewed only after they had completed their developmental math coursework and all grades for those courses were finalized. The interview data analysis was facilitated using Microsoft Excel and NVivo software.

Methodology

In order to find the influence of an online, mastery, and project-based developmental math curriculum on student achievement and attitude, this mixed methods study used the developmental math program data archived at the participating college in conjunction with interviews of students who participated in either the revised or the traditional developmental math programs. In this section the rationale and procedures for participant selection is provided along with a description of the quantitative instruments used for data collection. A description of the qualitative interview procedures is also provided. Next, the data analysis plan is explained, and threats to validity, issues of trustworthiness and ethics, and strategies for handling these threats and issues are also addressed.

Participant Selection Logic

The population of interest for this study included developmental mathematics students from colleges comparable to the participating Western United States rural community college. Students attending the participating college were required to take developmental math courses based on either their ACT math scores or their scores on the Accuplacer exam offered at the college. Since approximately 1500 students participated in the developmental math program annually, about 4500 students participated in the program during the first three years of implementation. Anticipating a moderate effect size of 0.15 and an alpha level of 0.05 for a multiple regression, a minimum sample size of about 204 students would be needed in order to have a statistical power level of 0.99 when using 7 independent variables. Thus, as the sample size for this study far exceeds this minimum, the expected power of this study's multiple regression analysis is quite high.

Based on standard procedures and policy at the college, identical course descriptions were used for both the revised and traditional sections of each developmental math course (i.e. PreAlgebra, Beginning Algebra, and Intermediate Algebra) in the print and online course catalog. Thus, students registering for courses based only on the course name and description assigned themselves to a revised or traditional course section without prior knowledge of the content delivery method to be used. Although students were still allowed to change their schedule during the first few weeks of classes, most students remained in the class in which they had originally enrolled. Even though the researcher had no control over which students enrolled in the revised or traditional courses, some randomness was achieved due to this process implemented by the college using identical course descriptions for both types of courses.

The archived program evaluation data used for this study was collected as part of the college's standard instructional practice and used for program evaluation during the first three years (i.e. Fall 2012 to Spring 2015) that the revised developmental math program was implemented. This archived data contained the final exam scores from almost all students who completed each course. The attitude and content knowledge pretest and posttest scores for participating students were also included in this set of data. However, there are fewer participating students with scores for both the pretest and posttest for attitude or content knowledge due to student transfers to a higher or lower level developmental math course, student attendance on the day of test administration, and teacher decisions to administer the pretests and posttests. In addition, the archived data included the gender, ethnicity, course level (PreAlgebra, Beginning Algebra, Intermediate Algebra), and course instructor for participating students.

A 2-tiered, intensity sampling strategy was used to select students for the interview phase of this study. First, potential developmental math students were grouped based on the teaching methodology (revised or traditional) used in their Spring 2015 course. Then three subgroups were formed from these two groups based on the academic performance of the students. More information regarding the criteria for each performance level group appears in the Qualitative Data and Analysis subsection under Research Question 3 in the Research Design and Rationale section of this chapter. Interviews from this sample of students provided a vivid picture of the core program elements based on their experiences (Patton, 2002). However, as these interviews took place approximately 2 years after the students completed the developmental mathematics program, the students' ability to recall their developmental mathematics experiences was a limiting factor to this study.

Instrumentation

Content knowledge. The pretests, posttests, and final exams used to assess content knowledge were designed by multiple math department faculty members at the participating college. One teacher was designated as lead teacher for each course level (i.e. PreAlgebra, Beginning Algebra, or Intermediate Algebra). This lead teacher was then responsible to make the initial draft of the assessment so that the key course objectives were each assessed. The key objectives of the PreAlgebra courses were for students to show proficiency with (a) arithmetic of signed numbers; (b) fractions, decimals, and percents; (c) order of operations; (d) unit conversions, rates, ratios, and proportions; (e) simplifying algebraic expressions; and (f) solving one- and two-step linear equations in on variable. The key objectives of the Beginning Algebra courses were for students to show proficiency with (a) solving and graphing linear equations in one and two variables; (b) solving linear inequalities in one variable; (c) arithmetic operations with polynomials; and (d) factoring polynomials. The key objectives of the Intermediate Algebra courses were for students to show proficiency with (a) functions; (b) solving and graphing linear inequalities in two variables; (c) solving and graphing absolute value equations and inequalities; (d) solving systems of linear equations involving two variables; (e) solving and graphing non-linear equations; and (f) performing arithmetic with complex numbers. The initial content knowledge of students was measured using a pretest composed of math problems directly tied to the aforementioned key course objectives of each developmental math course. These math problems were each in a multiple choice format, and the pretest score was the percentage of the test problems that the students answered correctly. Posttests were used as one measure of final content knowledge. These posttests were also composed of multiple choice math problems tied to the key course objectives. Final exam scores (composed of both multiple choice and short answer math problems) were also used to measure final content knowledge. The scores for the posttest and the final exam were also the percentage of the test problems that the students answered correctly.

Once completed the draft was then given for review to each faculty member who was teaching the course. The assessment draft was then edited based on the faculty feedback, thus establishing strong content validity for the assessment. The final versions of the pretest and posttest exams used identical problems with different algorithmically generated values. At the end of each semester, the same content knowledge pretests, posttests, and final exams were given in both the revised and traditional sections of the developmental math program. Since the content knowledge pretests and posttests and the final exams were created and reviewed by math content experts to measure well-defined mathematical skills for each course, these assessments have strong content validity (Teddlie & Tashakkori, 2009).

After the initial creation of the pretest and posttest exams, the pretest and posttest exams for consecutive semesters used the same problem templates but with different algorithmically generated values. As the posttest and the final exam were both designed to measure the same student learning outcomes of each course, a parallel-forms technique was applied to gauge how well the results of these two assessments correlated with each other, thus providing an estimate of test reliability. The first assumption that needed to be met in order to perform this correlation analysis between the content posttest scores and the final exam scores was that there needed to be a linear relationship between the two variables. The scatterplot in Figure 3 shows that this assumption was met as there was an approximately linear trend to the data points. An additional assumption that needed to be met was that the distribution of each variable needed to be approximately normal. Based on the normal Q-Q plots shown in Figure 4, the approximate linear trend for each variable indicates approximate normality in the distributions. So the correlation analysis was conducted, which yielded a Pearson correlation coefficient of .523. This result indicates that there was a moderate positive correlation between the content posttest scores and the final exam scores. Because these assessments were moderately aligned and because more students in the archived database had final exam scores than content posttest scores, final exam scores were used in the quantitative analysis as the measure of final content knowledge.

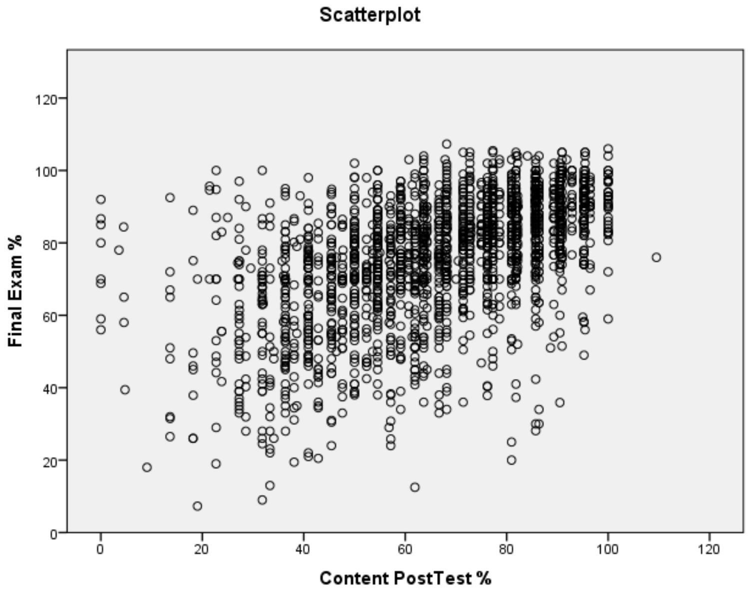

Figure 3. Scatterplot (final exam % and content posttest %)

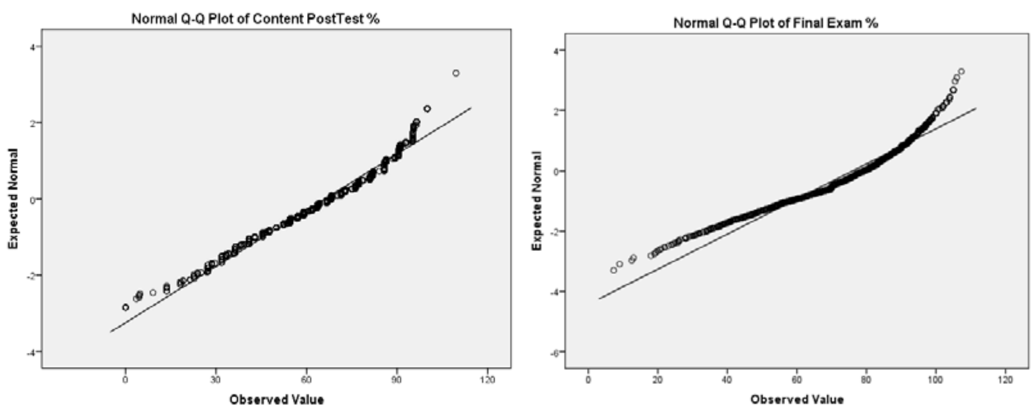

Figure 4. Normal Q-Q plots (final exam % and content posttest %)

Attitude. Initial and final attitude were measured using Tapia's (1996a, 1996b) Attitudes Toward Mathematics Inventory (ATMI) as a pretest and posttest. The four factors of math attitude measured via the ATMI are self-confidence, value, enjoyment, and motivation. The self-confidence items assess the level at which students associate anxiety, fear, and confidence with tasks involving mathematics. The value items assess the level at which students perceive math as necessary and important for everyday life.

The enjoyment items assess the level at which students associate feelings of joy and happiness with the study and use of mathematics. The motivation items assess the level at which students seek out opportunities to engage in mathematics. Each ATMI item uses a Likert scale (i.e. strongly disagree, disagree, neutral, agree, strongly agree). For scoring purposes student responses were coded as 0, 1, 2, 3, or 4 with 0 representing the most negative attitude towards math and 4 representing the most positive attitude towards math. Then the pretest and posttest score for each student was computed using the sum of each coded response. Thus, as the ATMI contains 40 items, the minimum score possible was 0 and the maximum score possible was 160.

Tapia (1996b) conducted a factor analysis on the ATMI to gauge its validity and reliability when used to measure attitude towards mathematics among students at the high school level. As is evident from the results in Table 1, the study indicated that the sense of security factor (also referred to as self-confidence) had excellent reliability, and the remaining three factors (i.e. value, motivation, and enjoyment) had good reliability. These results along with the instrument's overall Cronbach alpha coefficient of 0.97 indicated that the ATMI was very reliable at the high school level.

Table 1

ATMI Factor Analysis Results for High School Students

Factor	Cronbach Alpha	Item Examples
Sense of Security	0.95	17. I have a lot of self-confidence when it comes to mathematics.
Value	0.86	1. Mathematics is a very worthwhile and necessary subject.
Motivation	0.89	34. The challenge of math appeals to me.
Enjoyment	0.88	26. I like to solve new problems in mathematics.

Tapia and Marsh (2002) conducted a similar analysis with college students to determine if similar results would hold true for this new population. As is evident from the results in Table 2, this later study found that the sense of security and value factors had excellent reliability and the remaining two factors (i.e. motivation and enjoyment) had good reliability. These results once again showed that the ATMI was reliable at the college level as well. Tapia (1996b) also indicated that a blueprint of the domains requiring assessment was used during the item development stage to establish content validity. Review by two experienced mathematics instructors also helped to ensure strong content validity. Furthermore, strong construct validity was demonstrated for each item by using a homogeneity test the yielded an item-to-total correlation higher than 0.49

for each item. A copy of the ATMI and documentation of the email exchange granting permission to use the ATMI for the three year program evaluation at the participating college and for my dissertation can be found in Appendix A.

Table 2

ATMI Factor Analysis Results for College Students

Factor	Cronbach Alpha
Sense of Security	0.96
Value	0.93
Motivation	0.87
Enjoyment	0.88

Interviews. Potential interviewees were contacted and given the Interview Consent Form (Appendix B). This form provided a brief background on my study, the purpose of the interview, the interview procedures that were to be followed, the interview questions, the risks and benefits of being an interviewee, the privacy and confidentiality statement, and contact information for me and my Ph.D. supervisors. The interview questions were designed to prompt interviewees to describe their experiences within their developmental math class, their perceptions of content learning and mastery, and the attitudes and emotions associated with their experiences. More information regarding the qualitative sampling procedures appears in the "Qualitative Data Collection and Analysis" section of this chapter.

Procedures for Recruitment, Participation, and Data Collection

Quantitative procedures. During the first three years of implementation of the revised developmental math program at the participating college, routine data (i.e. content knowledge pretest and posttest scores, attitude pretest and posttest scores, final exam scores, final GPA, and other course-related and demographic information) was collected each semester from students in the revised and traditional developmental math classes. The final exam, final GPA, and demographic data were collected from almost all participating students. The content knowledge and attitude pretests and posttests were administered at the discretion of each developmental math teacher though the math department chair and school administration strongly encouraged each teacher to gather this data. In order to determine if these potential differences in instruction by different teachers were related to the final attitude and academic achievement of students, the course instructor was included in the multiple regression analyses. At the conclusion of each semester, all of the raw evaluation data was collected from each teacher and compiled into a single database by the math department. Demographic and other course-related data were originally gathered at the institution level from each student and was then given to the math department for inclusion in their database.

A formal application requesting access to this data was turned in to the Institutional Review Board (IRB) at the participating college. Once the application was approved by the IRB (See the Interview Informed Consent Form in Appendix B for the IRB approval number), any information that could be linked directly to individual students or teachers were stripped from the database, each student and teacher were assigned a unique identification number for use in the study, and then the resulting database was entrusted to me. Then throughout the study, the data was protected as regular backups of the original database as well as all digital files generated from that data were made regularly (Patton, 2002).

Qualitative procedures. To select the potential interviewees for the qualitative sample, I divided the students into two groups based on the instruction methodology used during their Spring 2015 developmental math course. Then each of these groups was further subdivided into three groups based on student performance level (for a total of six subgroups). From each subgroup I made a list of potential interviewees. Once this selection process was completed, I contacted students from each to subgroup to seek their consent to be interviewed for the study. Once two students from each subgroup had agreed to participate, each of these students (a total of 12) received and signed a copy of the Interview Consent Form (see Appendix B). If any of the selected students chose not to participate, another student with similar demonstrated math content knowledge was contacted to fill the opening. More information regarding the qualitative sampling procedures appears in the "Qualitative Data Collection and Analysis" section of this chapter.

One 30-40 minute interview was then scheduled and conducted with each participant. I recorded and transcribed each interview. Once the transcription was completed, each interviewee was given an opportunity to review any comments and interpretations made by me based on their interview. Then revisions were made based on participant reviews and feedback. In order to further protect the interview data and maintain the participants' confidentiality, the digital transcriptions and related digital files were backed up regularly and all identifiable participant information was appropriately protected and masked (Patton, 2002; QSR International, n.d.).

Data Analysis Plan

Software. The original quantitative database was given to me as a password-protected Excel spreadsheet. Computer software (i.e. Microsoft Excel and SPSS) was used to conduct preliminary descriptive analyses on the data. Then a multiple regression analysis was conducted. The qualitative interview data were transcribed, sorted, coded, and analyzed using Microsoft Word and NVivo software. Then I used NVivo tools (i.e. matrix coding, word frequency queries, etc.) and to determine the emergent themes from the data (QSR International, n.d.). The "Quantitative Analysis" and "Qualitative Analysis" sections for each research question contain more details regarding the analyses conducted on the quantitative and qualitative data.

Research question 1. How does the final student content knowledge in revised developmental mathematics courses (integrating online, mastery, and project-based learning) compare with that of students in traditional developmental mathematics courses at one community college in the Western United States?

H_0: The final student content knowledge in revised developmental mathematics courses (integrating online, mastery, and project-based learning) is not significantly different from that of students in traditional developmental mathematics courses at one community college in the Western United States.

H_1: The final student content knowledge in revised developmental mathematics courses (integrating online, mastery, and project-based learning) is significantly different from that of students in traditional developmental mathematics courses at one community college in the Western United States.

Quantitative analysis. SPSS was used to conduct a multiple regression using instruction methodology (revised or traditional), initial attitude, initial content knowledge, instructor, course level (PreAlgebra, Beginning Algebra, Intermediate Algebra), student gender, and student ethnicity as the independent variables and the final exam scores as the dependent variable. The multiple regression analysis determined how much of the variance in the dependent variable can be explained by the independent variables. Of the 4645 cases in the database, 3589 cases were missing values for one or more of the variables and were excluded from the regression. These data values were missing because some teachers opted not to administer the pretests or posttests for content knowledge or attitude in their classes. Of these missing cases, 1085 of them were from teachers that did not participate in administering the pretests and posttests at all. The remaining missing cases came from teachers that participated with some of their classes but not all. As 204 is the minimum sample size needed for a moderate effect size of 0.15 and an alpha level of 0.05, the remaining cases that were included in the analysis were still sufficient to have a statistical power level of 0.99.

Independent variables. Instruction methodology was a nominal variable which had “revised” (coded as 1) and “traditional” (coded as 0) as the possible values. Initial attitude was an interval variable with a score from 0 to 160 (0 indicating the most negative attitude towards mathematics and 160 indicating the most positive attitude towards mathematics). Initial content knowledge was a ratio variable that showed the percentage of math problems answered correctly on each test. The nominal instructor variable included a unique identifier for each participating teacher. Next, dichotomous dummy variables were created for use in the multiple regression analysis, and one of the teacher dummy variables served as the reference category. The nominal course level variable had “Math 0950” (for PreAlgebra, coded as 1), “Math 0990” (for Beginning Algebra, coded as 2), and “Math 1010” (for Intermediate Algebra, coded as 3) as possible values. Then course level dummy variables were created, and the "Math 1010" dummy variable served as the reference category. The nominal student gender variable had “Female” (coded as 0) and “Male” (coded as 1) as possible values. The nominal student ethnicity variable had possible values of “American Indian/Alaskan Native” (coded as 1), “Asian” (coded as 2), “Black or African American” (coded as 3), “Hispanic” (coded as 4), “Multiracial” (coded as 5), “Native Hawaii/Pacific Islander” (coded as 6), “Non-Resident/Alien” (coded as 7), “Unknown/Undisclosed” (coded as 8), and “White/Caucasian” (coded as 9). After this initial coding, dichotomous dummy variables were created for each ethnicity for use in the actual analysis, and the "White/Caucasian" dummy variable served as the reference category.

Dependent variable. Final content knowledge was a ratio variable that showed the percentage of math problems answered correctly on each test.

In order to justify the use of a multiple regression on the data set, the data was also checked to ensure that the required assumptions for this statistical test were met. An explanation of these assumptions and the procedures used to check them is provided below. The Data Analysis & Results section in Chapter 4 contains more details on how these assumptions were met.

Assumption 1. One continuous dependent variable is required (Laerd Statistics, 2015). The final exam scores meet this criterion of a continuous variable.

Assumption 2. There should be two or more continuous or nominal independent variables (Laerd Statistics, 2015). The instruction methodology, initial attitude, initial content knowledge, instructor, course level, student gender, and student ethnicity meet this criterion.

Assumption 3. Independence of observations is required (Laerd Statistics, 2015). This assumption was checked using the Durbin-Watson statistic.

Assumption 4. The independent variables must be linearly related (both individually and collectively) to the dependent variable (Green & Salkind, 2011; Laerd Statistics, 2015). To determine if the dependent variable is linearly related to independent variables collectively, a scatterplot was generated using the studentized residuals and the unstandardized predicted values (Laerd Statistics, 2015). To determine if the dependent variable is linearly related to each independent variable individually, a partial regression plot was created for each independent variable and the dependent variable (Laerd Statistics, 2015). As the nominal independent variables can be ignored (Laerd Statistics, 2015), attitude pretest scores and content pretest scores were the only independent variables for which partial regression plots were examined.

Assumption 5. There must be homoscedasticity of residuals (Laerd Statistics, 2015). To test this assumption in SPSS, the scatterplot of the studentized residuals and the unstandardized predicted values was used (Laerd Statistics, 2015).

Assumption 6. There must not be multicollinearity in the data (Green & Salkind, 2011; Laerd Statistics, 2015). To test this assumption in SPSS, correlation coefficients and VIF (variance inflation factor) values were examined (Laerd Statistics, 2015).

Assumption 7. The data should not include any significant outliers, high leverage points, or highly influential points (Laerd Statistics, 2015). Casewise diagnostics and studentized deleted residuals were used to find and remove outliers. To help find high leverage points, leverage values were computed during the regression procedure (Laerd Statistics, 2015). To help find highly influential points, Cook's Distance values were computed during the regression procedure (Laerd Statistics, 2015).

Assumption 8. There must be a normal distribution for the residuals (Green & Salkind, 2011; Laerd Statistics, 2015). To test this assumption in SPSS, a histogram and normal P-P plot were generated for the regression standardized residuals (Laerd Statistics, 2015).

Qualitative integration. The qualitative thematic analysis of the participating student interviews provided context to these quantitative results. Thorough comparisons of the quantitative and qualitative findings identified key features of the traditional and revised developmental math programs that influenced student learning. The "Qualitative Analysis" section under Research Question 3 contains more details.

Research question 2. How does the final student attitude towards mathematics in revised developmental mathematics courses (integrating online, mastery, and project-based learning) compare with that of students in traditional developmental mathematics courses at one community college in the Western United States?

H_0: The final student attitude towards mathematics in revised developmental mathematics courses (integrating online, mastery, and project-based learning) is not significantly different from that of students in traditional developmental mathematics courses at one community college in the Western United States.

H_1: The final student attitude towards mathematics in revised developmental mathematics courses (integrating online, mastery, and project-based learning) is significantly different from that of students in traditional developmental mathematics courses at one community college in the Western United States.

Quantitative analysis. SPSS was used to conduct a multiple regression using instruction methodology (revised or traditional), initial attitude, initial content knowledge, instructor, course level (PreAlgebra, Beginning Algebra, Intermediate Algebra), student gender, and student ethnicity as the independent variables and the attitude posttest scores as the dependent variable. The multiple regression analysis determined how much of the variance in the dependent variable can be explained by the independent variables. Of the 4645 cases in the database, 3959 cases were missing values for one or more of the variables and were excluded from the regression. These data values were missing because some teachers opted not to administer the pretests or posttests for content knowledge or attitude in their classes. Of these missing cases, 1127 of them were from teachers that did not participate in administering the pretests and posttests at all. The remaining missing cases came from teachers that participated with some of their classes but not all. As 204 is the minimum sample size needed for a moderate effect size of 0.15 and an alpha level of 0.05, the remaining cases that were included in the analysis were still sufficient to have a statistical power level of 0.99.

Independent variables. More information regarding the coding of the independent variables appears in the Quantitative Analysis section for Research Question 1.

Dependent variable. Final attitude was an interval variable with a score from 0 to 160 (0 indicating the most negative attitude towards mathematics and 160 indicating the most positive attitude towards mathematics).

In order to justify the use of a multiple regression on the data set, the data was also checked to ensure that the required assumptions for this statistical test were met. An explanation of these assumptions and the procedures used to check them is provided below. The Data Analysis & Results section in Chapter 4 contains more details on how these assumptions were met.

Assumption 1. One continuous dependent variable is required (Laerd Statistics, 2015). The attitude posttest scores meet this criterion of a continuous variable.

Assumption 2. There should be two or more continuous or nominal independent variables (Laerd Statistics, 2015). The instruction methodology (revised or traditional), initial attitude, initial content knowledge, instructor, course level, student gender, and student ethnicity meet this criterion.

Assumption 3. Independence of observations is required (Laerd Statistics, 2015). This assumption was checked using the Durbin-Watson statistic.

Assumption 4. The independent variables must be linearly related (both individually and collectively) to the dependent variable (Green & Salkind, 2011; Laerd Statistics, 2015). To determine if the dependent variable is linearly related to independent variables collectively, a scatterplot was generated using the studentized residuals and the unstandardized predicted values (Laerd Statistics, 2015). To determine if the dependent variable is linearly related to each independent variable individually, a partial regression plot was created for each independent variable and the dependent variable (Laerd Statistics, 2015). Once again the nominal independent variables were ignored (Laerd Statistics, 2015). Thus, the variables for content and attitude pretest scores were the only independent variable for which partial regression plots were examined.

Assumption 5. There must be homoscedasticity of residuals (Laerd Statistics, 2015). To test this assumption in SPSS, the scatterplot of the studentized residuals and the unstandardized predicted values was used (Laerd Statistics, 2015).

Assumption 6. There must not be multicollinearity in the data (Green & Salkind, 2011; Laerd Statistics, 2015). To test this assumption in SPSS, correlation coefficients and VIF (variance inflation factor) values were examined (Laerd Statistics, 2015).

Assumption 7. The data should not include any significant outliers, high leverage points, or highly influential points (Laerd Statistics, 2015). Casewise diagnostics and studentized deleted residuals were used to find and remove outliers. To help find high leverage points, leverage values were computed during the regression procedure (Laerd Statistics, 2015). To help find highly influential points, Cook's Distance values were computed during the regression procedure (Laerd Statistics, 2015).

Assumption 8. There must be a normal distribution for the residuals (Green & Salkind, 2011; Laerd Statistics, 2015). To test this assumption in SPSS, a histogram and normal P-P plot were generated for the regression standardized residuals (Laerd Statistics, 2015).

Qualitative integration. The qualitative thematic analysis of the participating student interviews provided context to these quantitative results. Thorough comparisons of the quantitative and qualitative findings identified key features of the traditional and revised developmental math programs that influenced student attitude. The "Qualitative Analysis" section under Research Question 3 contains more details.

Research question 3. How do students describe their experiences, attitudes, and content knowledge acquisition while participating in the revised and the traditional developmental mathematics programs at one community college in the Western United States?

Qualitative analysis. In addition to providing context to the quantitative findings from the first two research questions, the thematic analysis of the student interview data also offered critical insight into attributes, backgrounds, demographics, and experiences that also influenced student success within revised and traditional developmental mathematics programs. During the first stage of this thematic analysis, open coding was used in order to identify key concepts, ideas, and categories from the interview transcripts (Corbin & Strauss, 1990; Kolb, 2012). Then these categories were compared and analyzed in order to piece together emergent themes and patterns (Corbin & Strauss, 1990; Kolb, 2012). Finally, these themes were used to richly describe the influences of the revised and traditional developmental math programs on student success. These insights were critical as the quantitative and qualitative findings were woven together into a vibrant narrative of the experiences of the participating students. Where the quantitative and qualitative findings agreed, the triangulation of data added strength to the meta-inferences and instilled greater confidence in the conclusions. Conversely, discrepant cases where the quantitative and qualitative findings disagreed were also thoroughly examined and noted in order to inform future research and identify target populations of students that may benefit from alternative approaches to learning developmental mathematics (Freeman, deMarrais, Preissle, Roulston, & Pierre, 2007; Trend, 1979).

Threats to Validity

A critical step of every quality research study involves the identification and minimization of the potential threats to internal and external validity in order to ensure that accurate inferences and conclusions can be made from the analyses (Creswell, 2009; Creswell & Plano Clark, 2010). In the following section, potential threats to external validity that limit the generalizability of the results are explained along with measures taken to minimize the effects of each. Then explanations of the potential threats to internal validity and measures taken to minimize these threats are also provided.

External validity. The extent to which a study's results and conclusions can be generalized to alternative populations, settings, and situations depends heavily upon how well external validity threats a neutralized (Creswell, 2009). The first of these threats that must be addressed involves the interaction of selection and treatment. This threat limits the generalizability of results to students and colleges with similar characteristics as the participants in this study (Creswell, 2009). Specifically, the results should be generalized to colleges with a student body that is made up of predominantly white Caucasian students (about 94%), approximately 56% female, and about 65% full-time students. The representativeness of the student sample used in this study was also improved through the standard procedures of the college to use identical course catalog descriptions for both the revised and traditional developmental math courses of the same level, which allowed students to register for a course in a somewhat random manner. To further address this threat, future experimental research is recommended that examines these same research questions within various colleges and student populations.

According to Creswell (2009), generalizations of study results should also be restricted to settings similar to the study setting. Thus, results of this study are most pertinent to other colleges situated within a rural setting in the United States with developmental math class sizes of approximate 30 to 40 students. Furthermore, the external validity of this study was also improved due to the realistic instructional settings used (Spector et al., 2014). In addition, future research is also recommended that addresses these same research questions within other college settings (i.e. urban colleges, other countries, and various class sizes).

Last, the interaction of history and treatment can also threaten the external validity of a study. This threat limits generalizability of the study's findings to the timeframe in which the study was conducted, which was between Fall 2012 and Spring 2015 (Creswell, 2009). To further overcome this validity threat, future research is also recommended that replicates this study again at later times in order to see if similar results occur.

Internal validity. The use of a quasi-experimental nonequivalent control group design for the quantitative portion of this study was a major factor that limited the internal validity (Gall et al., 1996; Schenker & Rumrill, 2004). However, the participating college's use of identical course descriptions for both the revised and traditional versions of a developmental math course allowed students to register for a revised or traditional course in a somewhat random manner, which helped to overcome these limitations by minimizing participant selection threats (Creswell, 2009). This random assignment also helped minimize the threat of maturity by creating control and treatment groups with similar student age distributions (Creswell, 2009). Furthermore, the threat of maturity was also reduced due to the short duration (a 16-week semester) of each developmental math course. Conversely, the 16-week course duration was also long enough to ensure that participating students would not recall specifics about the content knowledge and attitude pretests while taking the posttests at the end of the semester. Potential testing and instrumentation threats were further reduced by creating pretests and posttests that used identical problem templates but with different algorithmically generated values. More details regarding the process used to create the pretests and posttests appears in the Instrumentation section of this chapter.

Issues of Trustworthiness

To improve the dependability and credibility of the qualitative analysis, the participating students were given an opportunity to verify the accuracy of summaries and interpretations resulting from their comments, and data triangulation was used through the comparison of the qualitative and quantitative results (Creswell, 2009; Creswell & Plano Clark, 2010; Teddlie & Tashakkori, 2009). In addition, thick descriptions of the research context and setting were used to improve the transferability of findings (Creswell, 2009; Teddlie & Tashakkori, 2009). In order to establish confirmability for the qualitative analysis, I clarified any researcher bias by fully disclosing experiences, perceptions, and prejudices that would influence the research approach and interpretations for the study (Creswell, 2013). In order to help identify and describe researcher bias, I maintained a reflexive journal while collecting and analyzing the interview data (Teddlie & Tashakkori, 2009). To further improve the confirmability and credibility of the qualitative analysis, negative cases were also discussed in detail (Creswell, 2013; Patton, 2002; Teddlie & Tashakkori, 2009). Finally, I randomly selected two of the interviews after initial coding of all interviews was completed. These randomly selected interviews were then coded again from scratch and compared with the original coding to establish intracoder reliability.

Ethical procedures. In order to gain access to secondary data and obtain approval to interview developmental math students, a formal application was completed and turned in to the Institutional Review Board (IRB) at the participating college. Once the application was approved by the IRB, any information connected to the quantitative data that could be linked directly to individual students was stripped from the database and each student was assigned a unique identification number, and then the resulting database was entrusted to me. Quantitative analyses were then performed on the data in this database. The archival nature of the quantitative data also ensured that I was not able to influence participating student grades in their developmental math courses as their grades were already finalized well before the commencement of this study.

In addition, I also searched this database to find the richest cases of developmental mathematics students to interview based upon academic performance in their final developmental math course (i.e. Intermediate Algebra). Then these students were contacted and asked to participate in an interview. Each potential interviewee was asked to read and sign an interview consent form prior to their participation in the study. The list of potential interviewees also had several extra students listed within each academic performance level in case some contacted students declined to participate. In order to protect and minimize risk to these students, this study did not include any identifiable information for these students either in their interview transcripts or when referring to their interviews. In addition, pseudonyms were used when referencing specific interviewees. Furthermore, most of the interviewees had finished their coursework at the participating community college due to the fact that the interviews took place approximately two years after the students completed their developmental math program. Thus, I was not able to influence past or future grades of these students.

As a measure to protect participant confidentiality, all digital data files used for the quantitative and qualitative analyses were password protected where possible. Furthermore, I was the sole person with access to these data files. In order to further protect the data, regular backups of the original database as well as all digital files generated from that data were made often and stored on a flash drive and two different computers (Patton, 2002). At the conclusion of this study, all digital data files (including backups) were safely stored. After five years this stored data will be permanently deleted.

Summary

The quantitative portion of this convergent parallel mixed methods case study used a multiple regression on archived data to determine how much of the variation in the final math attitude and content knowledge of developmental math students can be explained by instruction methodology (revised or traditional), initial attitude, initial content knowledge, instructor, course level (PreAlgebra, Beginning Algebra, Intermediate Algebra), gender, and ethnicity. An intensity sample of these participating students was also selected to participate in an interview to determine their shared developmental mathematics experiences. After the quantitative and qualitative analyses were completed, the results were then integrated to make meta-inferences and provide a more thorough explanation of the overall effectiveness of the revised program and also identified key program elements that influence student success (Swift, 2012; Teddlie & Tashakkori, 2009).

Chapter 4: Results

The purpose of this study was to analyze the impact of one college's redesigned developmental math program (integrating online, mastery, and project-based learning approaches) compared with the traditional program which utilized predominantly direct instruction and lecture-based learning strategies. The first research question focused on how the final content knowledge compared between students in the revised and traditional programs. The second research question focused on how the final attitude towards mathematics compared between students in the revised and traditional programs. The third research question focused on how students described their experiences, attitudes, and content knowledge acquisition in the revised and traditional developmental math programs. In this chapter, details pertaining to the study's setting, participant demographics, and data collection procedures are explained. Then the data analysis process, results, and evidence of trustworthiness are presented.

Study Setting

As outlined in Chapter 3, the study was conducted at a community college in the Western United States. The archived data used was originally gathered by the participating college and math department from Fall 2012 to Spring 2015 as part of the college's routine program evaluation procedures. As this study was conducted about 2 years after the last of this archived data was originally collected, there were no personal or organizational conditions from this study that influenced student participation in the revised or traditional developmental math programs at that time.

For the qualitative portion of the study, participating students had the option of being interviewed on the phone, in-person, or by email. For the seven interviewees who chose to have a phone interview, I ensured that I was in a room completely free of distractions, but I was not able to control the environment of the interviewees. There were no obvious signs of distractions or adverse conditions apparent on the part of the interviewees during these phone conversations. I was also unable to control the environment for the one interviewee who opted to conduct the interview via email. For the remaining four interviewees, we conducted the interviews at the campus of the participating college in a room distanced from the main campus foot traffic with minimal distractions. This setting allowed the interviewees to feel safe sharing their thoughts while still being in an environment with which they were familiar.

Demographics

The racial makeup of the participating college and its surrounding community was approximately 85% White Caucasian and 14% from other races. Approximately half of the population was female and the other half male. The 12 students interviewed for the qualitative portion of this study were all taking Intermediate Algebra in the Spring 2015. The racial makeup of these interviewees was approximately 92% White Caucasian and 8% from other races. Half of the interviewees were male, and half were female. Additionally, 11 of the interviewees took face-to-face developmental math courses while one interviewee took an online variation of a traditional course. There were also two of the interviewees (both in the traditional low performance group) that participated in both the revised and traditional developmental math programs while the other 10 interviewees (6 in the revised groups, 4 in the traditional groups) participated solely in either the revised or traditional programs.

Data Collection

The archived data used for this study included 4645 cases of students who participated in the revised and the traditional developmental math programs at the participating community college from Fall 2012 to Spring 2015. After removing cases that were missing values or that were outlier, leverage, or highly influential points, 1040 cases were used in the regression for research question 1, and 655 cases were used in the regression for research question 2. Additionally, 12 of these participating students were interviewed for the qualitative portion of this study. The duration of the interviews was between 15 and 30 minutes. Of these interviewees, four were interviewed in-person on the campus of the participating college, seven were interviewed by phone, and one was interviewed via email. All interviews were conducted between January and February 2017. The Informed Interview Consent Form in Appendix B contains the list of questions asked during these interviews. Each interview was audio recorded and then transcribed using Microsoft Word. The transcriptions were then imported into NVivo for coding and thematic analysis. Microsoft Excel was also used to help with the thematic analysis. All data collection procedures went as outlined in Chapter 3.

Data Analysis & Results

Thorough descriptions of the quantitative and qualitative data analysis and results for research questions 1, 2, and 3 are provided in this section. Then evidence supporting the trustworthiness of this study is shared.

Research Question 1

How does the final student content knowledge in revised developmental mathematics courses (integrating online, mastery, and project-based learning) compare with that of students in traditional developmental mathematics courses at one community college in the Western United States?

H_0: The final student content knowledge in revised developmental mathematics courses (integrating online, mastery, and project-based learning) is not significantly different from that of students in traditional developmental mathematics courses at one community college in the Western United States.

H_1: The final student content knowledge in revised developmental mathematics courses (integrating online, mastery, and project-based learning) is significantly different from that of students in traditional developmental mathematics courses at one community college in the Western United States.

Quantitative analysis & results. To answer research question 1, a multiple regression analysis was conducted to predict final exam score (dependent variable) using instruction methodology (revised or traditional), initial attitude, initial content knowledge, instructor, course level (PreAlgebra, Beginning Algebra, Intermediate Algebra), student gender, and student ethnicity. The multiple regression analysis required several assumptions to be met. An explanation of these assumptions and the procedures used to check them is provided below.

Assumption 1. One continuous dependent variable is required (Laerd Statistics, 2015). The final exam scores meet this criterion of a continuous variable.

Assumption 2. There should be two or more continuous or nominal independent variables (Laerd Statistics, 2015). The instruction methodology (revised or traditional), initial attitude, initial content knowledge, instructor, course level, student gender, and student ethnicity meet this criterion.

Assumption 3. Independence of observations is required (Laerd Statistics, 2015). This assumption was checked using the Durbin-Watson statistic. Because the Durbin-Watson statistic of 1.860 (shown in Table 3) is very close to 2, there was an independence of errors. Thus, this assumption was met.

Table 3

Multiple Regression Model Summary (Final Content Knowledge)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.508	.259	.241	14.66854852	1.860

Dependent Variables: Final Exam %

Assumption 4. The independent variables must be linearly related (both individually and collectively) to the dependent variable (Green & Salkind, 2011; Laerd Statistics, 2015). To determine if the dependent variable is linearly related to independent variables collectively, a scatterplot (see Figure 5) was generated using the studentized residuals and the unstandardized predicted values (Laerd Statistics, 2015). As the residuals in the plot are scattered with no apparent non-linear pattern, the final exam scores (dependent variable) and the independent variables likely had a linear relationship.

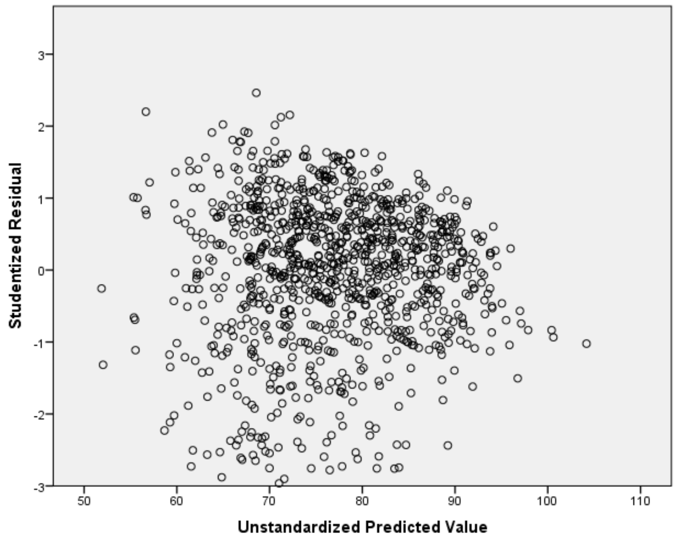

Figure 5. Scatterplot (residual and predicted value, final exam %)

To determine if the dependent variable is linearly related to each independent variable individually, a partial regression plot was created for each independent variable and the dependent variable (Laerd Statistics, 2015). As the nominal independent variables can be ignored (Laerd Statistics, 2015), attitude pretest scores and content pretest scores were the only independent variables for which partial regression plots were examined. As shown in Figures 6 and 7, these partial regression plots showed an approximately linear relationship between final exam scores and attitude pretest scores as well as between final exam scores and content pretest scores. Thus, both requirements for assumption 4 were met.

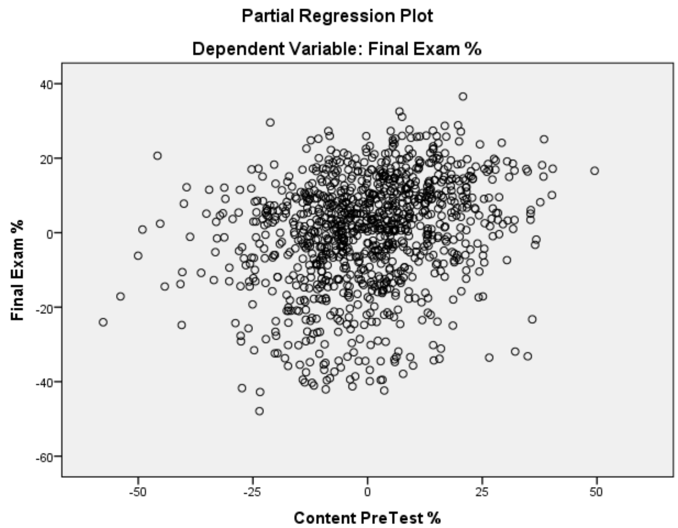

Figure 6. Partial regression plots (final exam % and content pretest %)

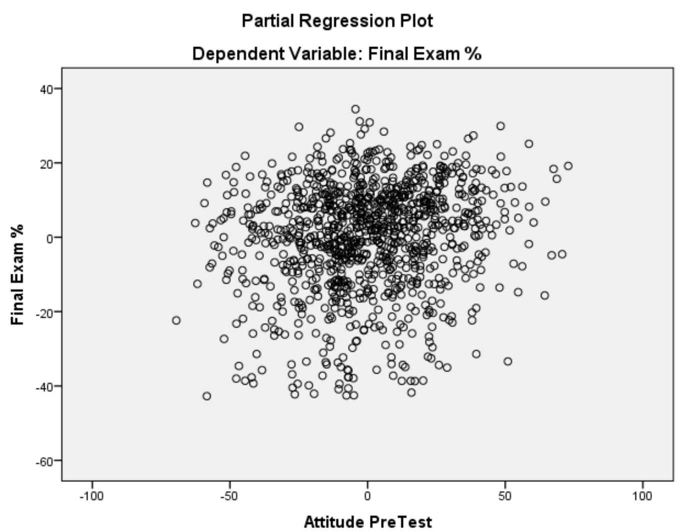

Figure 7. Partial regression plots (final exam % and attitude pretest %)

Assumption 5. There must be homoscedasticity of residuals (Laerd Statistics, 2015). To test this assumption in SPSS, the scatterplot of the studentized residuals and the unstandardized predicted values was used (Laerd Statistics, 2015). As is clear from the scatterplot in Figure 5, the dispersion of the residuals seems to be random, indicating that this assumption was met.

Assumption 6. There must not be multicollinearity in the data (Green & Salkind, 2011; Laerd Statistics, 2015). To test this assumption in SPSS, correlation coefficients and VIF (variance inflation factor) values were examined (Laerd Statistics, 2015). When the multiple regression was initially conducted, all independent variables had VIF values less than 10 except for the class type variable and one of the dummy variables for one the developmental math teachers. These variables also showed a strong negative correlation ($r = -.895$) with the Class Type variable. Upon closer inspection it was clear that this teacher had only taught traditional sections of the developmental math classes and had taught nearly 30% of those classes overall. Thus, to resolve the multicollinearity issue in the analysis, the multiple regression was run again with this variable excluded. On the second time, all variables had VIF values that were less than 10, indicating that there was minimal multicollinearity in the data. In addition, the correlation coefficients for each of the independent variables had values less than .7. Thus, this assumption was also met.

Assumption 7. The data should not include any significant outliers, high leverage points, or highly influential points (Laerd Statistics, 2015). Using casewise diagnostics and studentized deleted residuals, 11 outliers were detected and removed from the analysis (Laerd Statistics, 2015). To help find high leverage points, leverage values were computed during the regression procedure (Laerd Statistics, 2015). The five records with leverage values greater than .2 were removed from the analysis. To help find highly influential points, Cook's Distance values were computed during the regression procedure (Laerd Statistics, 2015). No records had a Cook's Distance above 1. Thus, after the removal of the outliers, high leverage point, and highly influential points, this assumption was met.

Assumption 8. There must be a normal distribution for the residuals (Green & Salkind, 2011; Laerd Statistics, 2015). To test this assumption in SPSS, a histogram and normal P-P plot were generated for the regression standardized residuals (Laerd Statistics, 2015). From the histogram in Figure 8 and the normal P-P plot in Figure 9, the standardized residual appear to be approximately normal. Thus, this assumption was met.

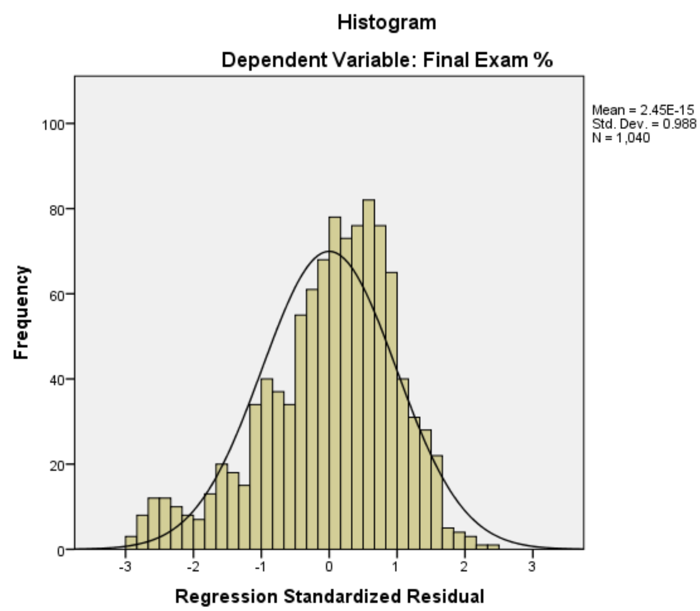

Figure 8. Histogram of standardized residuals (final exam %)

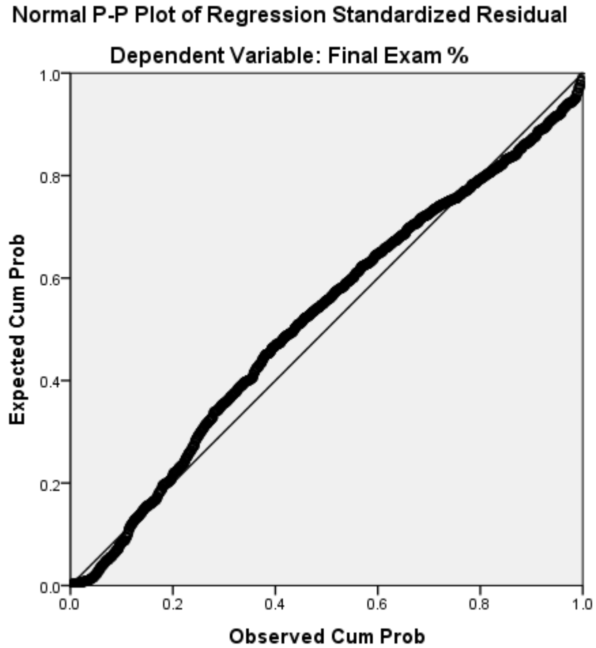

Figure 9. Normal P-P plot of standardized residuals (final exam %)

From the Model Summary (see Table 3), the overall model has a correlation coefficient *r* of .508, a coefficient of determination r^2 of .259, and an adjusted r^2 of .241. Thus, about 24.1% of the variation in final exam scores can be explained by this multiple regression model. Cohen (1988) suggested that an *r* greater than or equal to .5 (as is the case with this model) suggests a large effect size. Furthermore, from Table 4 it is clear that the independent variables used in this model significantly predicted final exam score, $F(24, 1015) = 14.746,\ p < .001$. Figure 10 contains the resulting multiple regression equation, and Table 5 contains a list of the variable coefficients and significance levels.

Table 4

Multiple Regression ANOVA (Final Content Knowledge)

Model	N		Sum of Squares	df	Mean Square	F	Sig.
1	1040	Regression	76148.781	24	3172.866	14.746	.000
		Residual	218393.810	1015	215.166		
		Total	294542.591	1039			

Dependent Variables: Final Exam %

$$
\begin{aligned}
(Final\ Exam\ \%) = \\
& 67.439 + 0.248(Content\ PreTest\ \%) + 0.093(Attitude\ PreTest\ Score) \\
& -16.679(Class\ Type) + 5.851(Teacher3) + 8.290(Teacher4) + 1.126(Teacher5) \\
& -2.534(Teacher6) + 2.280(Teacher10) + 10.506(Teacher12) \\
& +7.483(Teacher13) + 0.145(Teacher15) + 2.968(Teacher21) \\
& +3.775(Teacher23) + 7.096(Teacher25) - 7.415(American\ Indian\ or\ Alaskan) \\
& -9.641(Black\ or\ African\ American) - 6.279(Hispanic) - 8.421(Multiracial) \\
& -3.836(Native\ Hawaiaan\ or\ Pacific\ Islander) + 2.737(NonResident\ or\ Alien) \\
& +2.939(Unknown\ or\ Undisclosed) + 9.881(Math\ 0950\ PreAlgebra) \\
& +2.510(Math\ 0990\ Beginning\ Algebra) - 1.797(Gender)
\end{aligned}
$$

Figure 10. Multiple regression equation (final exam %)

Table 5

Multiple Regression Analysis Summary (Final Content Knowledge)

	Unstandardized Coefficients		Standardized Coefficients		
Variable	B	SE_B	Beta	t	Sig.
(Constant)	67.439	2.066		32.650	0.000
Content PreTest %	0.248	0.030	0.253	8.174	0.000
Attitude PreTest Score	0.093	0.019	0.142	4.965	0.000
Class Type (Trad=0, Rev=1)	-16.679	1.389	-0.445	-12.010	0.000
Teacher3	5.851	2.549	0.068	2.295	0.022
Teacher4	8.290	1.963	0.133	4.224	0.000
Teacher5	1.126	2.092	0.016	0.538	0.591
Teacher9	-2.534	3.618	-0.020	-0.700	0.484
Teacher10	2.280	1.800	0.039	1.266	0.206
Teacher12	10.506	3.391	0.088	3.098	0.002
Teacher13	7.483	1.959	0.136	3.820	0.000
Teacher15	0.145	3.193	0.001	0.045	0.964
Teacher21	2.968	4.763	0.017	0.623	0.533
Teacher23	3.775	2.420	0.050	1.560	0.119
Teacher25	7.096	2.450	0.085	2.897	0.004
Ethnicity=American Indian/Alaskan Native	-7.415	6.597	-0.030	-1.124	0.261
Ethnicity=Black or African American	-9.641	2.841	-0.094	-3.393	0.001
Ethnicity=Hispanic	-6.279	2.150	-0.080	-2.920	0.004
Ethnicity=Multiracial	-8.421	3.159	-0.074	-2.666	0.008
Ethnicity=Native Hawaii/Pacific Islander	-3.836	3.069	-0.035	-1.250	0.212
Ethnicity=Non-Resident/Alien	2.737	4.027	0.019	0.680	0.497
Ethnicity=Unknown/Undisclosed	2.939	4.969	0.016	0.591	0.554
Course=Math 0950	9.881	2.049	0.194	4.822	0.000
Course=Math 0990	2.510	1.303	0.073	1.926	0.054
Gender (Female=0, Male=1)	-1.797	1.017	-0.052	-1.767	0.077

Dependent Variable: Final Exam %

The results provided below indicate the effects of the class type (i.e. main independent variable) on the final content knowledge (dependent variable) while controlling for the effects of the remaining independent variables. A significance level of .05 was used for all regression variables. Thus, there is a 5% chance of making a Type I Error (i.e. rejecting the null hypothesis erroneously).

The class type ($p < .001$) did have a significant impact on the final exam scores. Final exam scores for students in the revised developmental math courses tended to be about 16 percentage points lower on average than those in the traditional courses as is evident from the class type coefficient of -16.679. The content and attitude pretest scores (both with $p < .001$) also significantly impacted final exam scores; however, the coefficients of 0.248 and 0.093 indicate that the impact was only a fraction of a percentage point.

Of the 26 teachers in the database, 13 teachers opted not to administer the content or attitude pretests or posttests in their classes. Thus, these teachers were removed from the analysis. One teacher also showed a very strong correlation with the class type variable and needed to be removed from the analysis. Of the remaining teachers, there were 5 teachers (each with $p < .03$) that significantly impacted final exam scores. The coefficients for these teachers suggest that teachers impacted student final exam scores by up to 11 percentage points. Furthermore, the coefficients indicate a good deal of variability in the impact that each teacher had on final exam scores.

The White/Caucasian ethnicity served as the reference category for the ethnicity variables. Of all of the ethnicity types used, students with Black or African American ($p = .001$), Hispanic ($p = .004$), and Multiracial ($p = .008$) ethnicities performed significantly lower (by 6 to 10%) on the final exams than the White/Caucasian students.

The Math 1010 (Intermediate Algebra) course served as the reference category for the course. Students in the Math 0950 (PreAlgebra) courses ($p < .001$) performed almost 10 percentage points higher on their final exams than those in the Math 1010 courses. The Math 0990 (Beginning Algebra) students ($p = .054$) did not perform significantly different than the Math 1010 students. With $p = .077$, gender (i.e. Male or Female) also did not significantly impact final exam scores.

Qualitative integration. While the quantitative analysis indicated that students in the revised developmental math courses achieved lower scores on their final exams than did the students in the traditional courses, 9 out of the 12 students interviewed indicated that they had mastered that content fairly well. Table 6 contains several direct quotations from these interviewees. These 9 interviewees included students in revised and traditional courses as well as students in all three achievement groups. The Interpretation of Findings section of Chapter 5 contains a detailed interpretation for this discrepancy.

Table 6

Interviewee Comments: Good Content Mastery

Interviewee Name (Pseudonyms)	Responses the Prompt *Describe how well you were able to master the math topics taught in your developmental math courses.*
(Aaron, personal communication, January 16, 2017)	"Often I felt…because math was never my strong suit…but with those developmental classes (the iLearn and everything), I was finding myself with the lowest grade ever as a high B or an A-. But mainly I would always pass in those classes with A's. I never found them a problem I think. They were absolutely … I had never learned that same math quite that way before. So I think it helped me."
(Abby, personal communication, January 17, 2017)	"I felt really good."
(Bill, personal communication, January 14, 2017)	"Well, I mastered it fairly well. As far as the final and the tests go, I did proficient in the class."
(Brittany, personal communication, January 20, 2017)	"I would say pretty well. You know, some of the longer story problems…maybe not so much."
(Carla, personal communication, January 30, 2017)	"I actually learned them pretty well. Math 1010 was essentially the third time I had taken that class. And my test scores went up significantly from the times I took the class in high school because I had a better understanding of the concepts and my test scores were definitely higher."
(Don, personal communication, January 31, 2017)	"I think I learned them pretty good."
(Erik, personal communication, January 28, 2017)	"Because most of it was a review, pretty good. Because usually you'd run into something like I've done this before but I can't remember. So you would try the problems, and if you missed too many, it would send you through the lesson, and you'd get a good review and can continue. And sometimes if you weren't quite getting it, you'd have to keep going through it. I think it's pretty good."
(Evan, personal communication, January 17, 2017)	"For the most part pretty well because … that is one thing I will give those online courses … because they are so strict…once you get it figured out and you learn it…by the time you learned it, you've done it enough times that it rattles around in your head for a good while."
(Fred, personal communication, January 23, 2017)	"Really well because I still have a lot of the notes in the notebooks that I've saved. I have that information now because it's on paper. And it just … makes it really nice."

Research Question 2

How does the final student attitude towards mathematics in revised developmental mathematics courses (integrating online, mastery, and project-based learning) compare with that of students in traditional developmental mathematics courses at one community college in the Western United States?

H_0: The final student attitude towards mathematics in revised developmental mathematics courses (integrating online, mastery, and project-based learning) is not significantly different from that of students in traditional developmental mathematics courses at one community college in the Western United States.

H_1: The final student attitude towards mathematics in revised developmental mathematics courses (integrating online, mastery, and project-based learning) is significantly different from that of students in traditional developmental mathematics courses at one community college in the Western United States.

Quantitative analysis & results. To answer research question 2, a multiple regression analysis was conducted to predict attitude posttest score (dependent variable) using instruction methodology (revised or traditional), initial attitude, initial content knowledge, instructor, course level (PreAlgebra, Beginning Algebra, Intermediate Algebra), student gender, and student ethnicity. The multiple regression analysis required several assumptions to be met. An explanation of these assumptions and the procedures used to check them is provided below.

Assumption 1. One continuous dependent variable is required (Laerd Statistics, 2015). The attitude posttest scores meet this criterion of a continuous variable.

Assumption 2. There should be two or more continuous or nominal independent variables (Laerd Statistics, 2015). The instruction methodology (revised or traditional), initial attitude, initial content knowledge, instructor, course level, student gender, and student ethnicity meet this criterion.

Assumption 3. Independence of observations is required (Laerd Statistics, 2015). This assumption was checked using the Durbin-Watson statistic. Because the Durbin-Watson statistic of 2.052 (shown in Table 7) is very close to 2, there was an independence of errors. Thus, this assumption was met.

Table 7

Multiple Regression Model Summary (Final Attitude)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.856	.732	.722	14.5968	2.052

Dependent Variables: Attitude PostTest Scores

Assumption 4. The independent variables must be linearly related (both individually and collectively) to the dependent variable (Green & Salkind, 2011; Laerd Statistics, 2015). To determine if the dependent variable is linearly related to independent variables collectively, a scatterplot (see Figure 11) was generated using the studentized residuals and the unstandardized predicted values (Laerd Statistics, 2015). As the residuals in the plot are scattered with no apparent non-linear pattern, the attitude posttest scores (dependent variable) and the independent variables likely had a linear relationship.

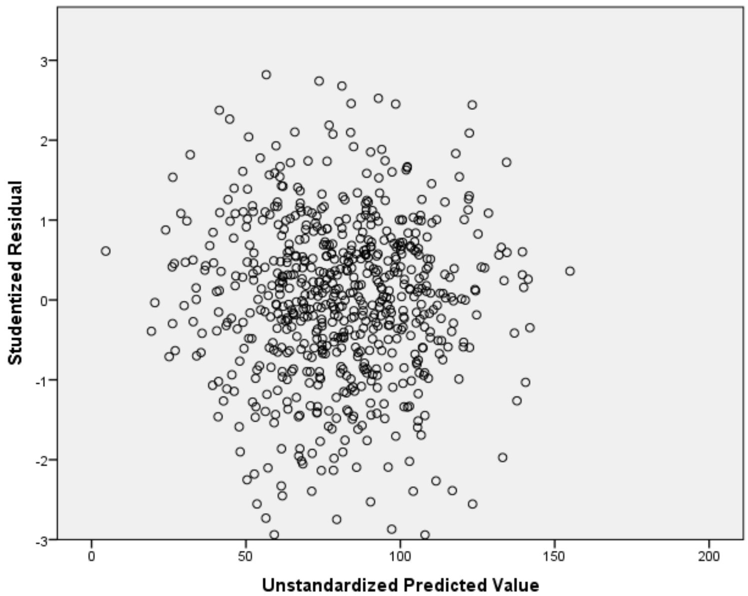

Figure 11. Scatterplot (residual and predicted value, attitude posttest)

To determine if the dependent variable is linearly related to each independent variable individually, a partial regression plot was created for each independent variable and the dependent variable (Laerd Statistics, 2015). Once again the nominal independent variables can be ignored (Laerd Statistics, 2015). Thus, the variables for attitude pretest scores and content pretest scores were the only independent variables for which partial regression plots were examined. As shown in Figures 12 and 13, the partial regression plots showed an approximately linear relationship between attitude posttest scores and content pretest scores and a strong linear relationship between attitude posttest scores and attitude pretest scores. Thus, both requirements for assumption 4 were met.

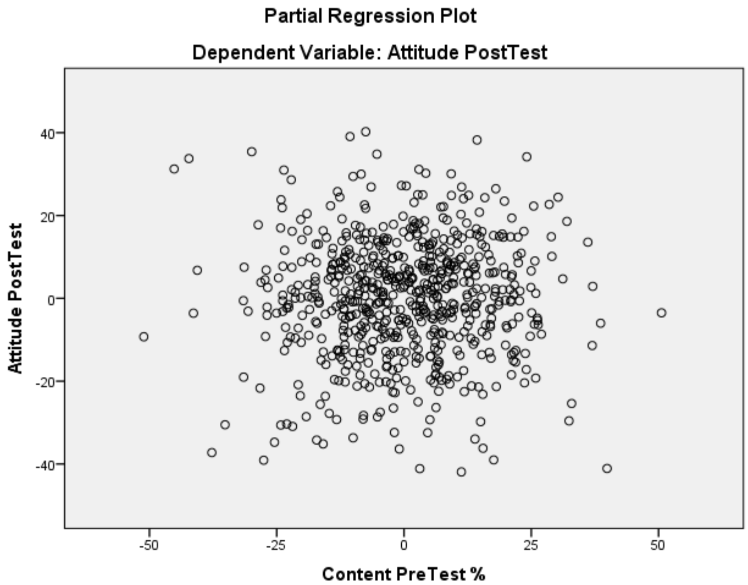

Figure 12. Partial regression plots (attitude posttest and content pretest %)

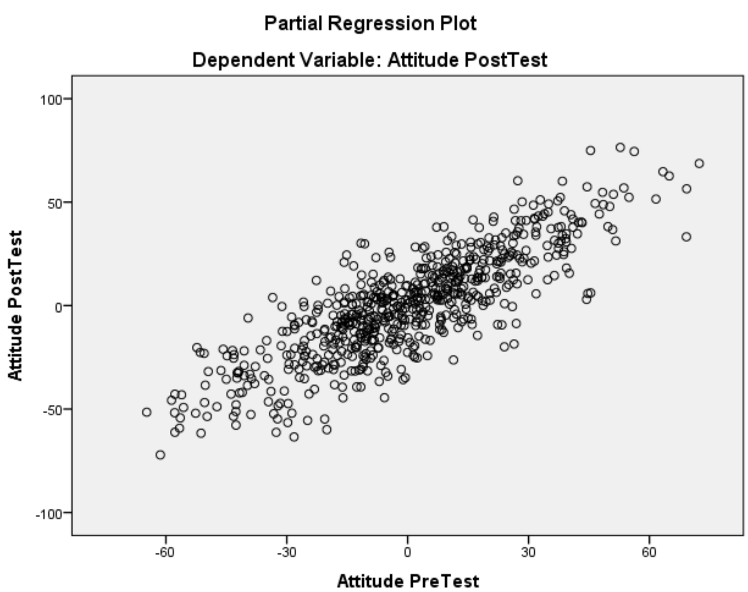

Figure 13. Partial regression plots (attitude posttest and attitude pretest %)

Assumption 5. There must be homoscedasticity of residuals (Laerd Statistics, 2015). To test this assumption in SPSS, the scatterplot of the studentized residuals and the unstandardized predicted values was used (Laerd Statistics, 2015). As is clear from the scatterplot in Figure 11, the dispersion of the residuals seems to be random, indicating that this assumption was met.

Assumption 6. There must not be multicollinearity in the data (Green & Salkind, 2011; Laerd Statistics, 2015). To test this assumption in SPSS, correlation coefficients and VIF (variance inflation factor) values were examined (Laerd Statistics, 2015). When the multiple regression was initially conducted, all variables had VIF values less than 10 except for one of the dummy variables for one the developmental math teachers. The same variable also showed a strong negative correlation ($r = -.933$) with the Class Type variable. Upon closer inspection it was clear that this teacher had only taught traditional sections of the developmental math classes and had taught nearly 30% of those classes. Thus, to resolve the multicollinearity issue in the analysis, the multiple regression was run again with this variable excluded. On the second time, all variables had VIF values that were less than 10, indicating that there was minimal multicollinearity in the data. Thus, this assumption was also met.

Assumption 7. The data should not include any significant outliers, high leverage points, or highly influential points (Laerd Statistics, 2015). Using casewise diagnostics and studentized deleted residuals, 11 outliers were detected and removed from the analysis (Laerd Statistics, 2015). To help find high leverage points, leverage values were computed during the regression procedure (Laerd Statistics, 2015). The 20 records with leverage values greater than .2 were removed from the analysis. To help find highly influential points, Cook’s Distance values were computed during the regression procedure (Laerd Statistics, 2015). No records had a Cook's Distance above 1. Thus, after the removal of the outliers, high leverage point, and highly influential points, this assumption was met.

Assumption 8. There must be a normal distribution for the residuals (Green & Salkind, 2011; Laerd Statistics, 2015). To test this assumption in SPSS, a histogram and normal P-P plot were generated for the regression standardized residuals (Laerd Statistics, 2015). From the histogram in figure 14 and the normal P-P plot in figure 15, the standardized residual appears to be approximately normal. Thus, this assumption was met.

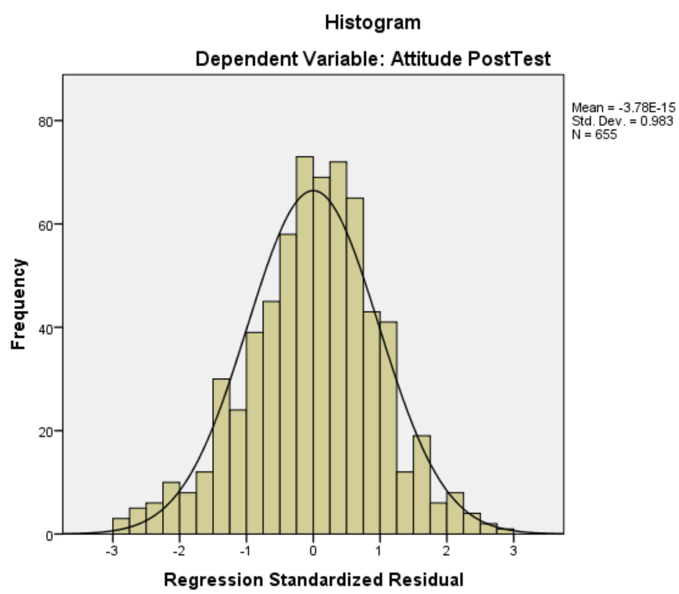

Figure 14. Histogram of standardized residuals (attitude posttest)

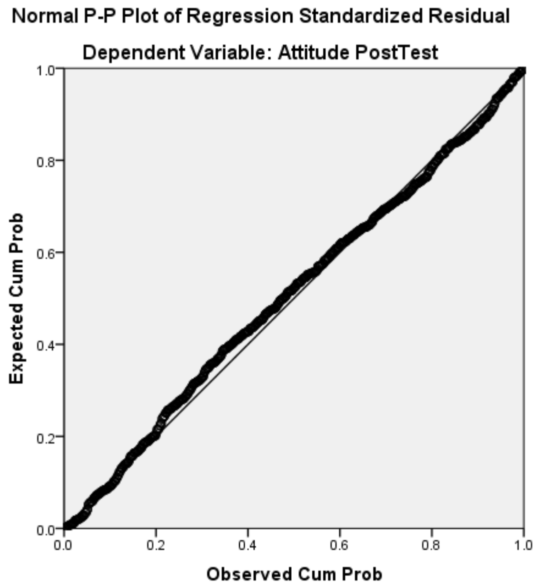

Figure 15. Normal P-P plot of standardized residuals (attitude posttest)

From the Model Summary (see Table 7), the overall model has a correlation coefficient *r* of .858, a coefficient of determination r^2 of .736, and an adjusted r^2 of .726. Thus, about 72.6% of the variation in attitude posttest scores can be explained by this multiple regression model. Cohen (1988) suggests that an *r* between greater than .5 (as is the case with this model) suggests a large effect size. Furthermore, from Table 8 it is clear that the independent variables used in this model significantly predicted attitude posttest score, $F(22, 632) = 79.924,\ p < .001$. Figure 16 contains the resulting multiple regression equation, and Table 9 contains a list of the variable coefficients and significance levels.

Table 8

Multiple Regression ANOVA (Final Attitude)

Model	N		Sum of Squares	df	Mean Square	F	Sig.
1	655	Regression	367056.058	22	16684.366	79.924	.000
		Residual	131932.363	632	208.754		
		Total	498988.421	654			

Dependent Variables: Attitude PostTest

$$
\begin{aligned}
&(Attitude\ PostTest\ Score) = \\
&\quad 7.927 + 0.023(Content\ PreTest\ \%) + 0.887(Attitude\ PreTest\ Score) \\
&\quad -2.603(Class\ Type) + 0.638(Teacher3) + 6.593(Teacher4) + 0.621(Teacher5) \\
&\quad -1.773(Teacher10) - 3.171(Teacher12) - 2.577(Teacher13) \\
&\quad +7.893(Teacher15) - 0.488(Teacher21) + 4.260(Teacher23) \\
&\quad -1.543(Teacher25) - 12.356(Black\ or\ African\ American) + 1.951(Hispanic) \\
&\quad -8.925(Multiracial) - 2.494(Native\ Hawaiaan\ or\ Pacific\ Islander) \\
&\quad +2.383(NonResident\ or\ Alien) + 3.055(Unknown\ or\ Undisclosed) \\
&\quad +4.794(Math\ 0950\ PreAlgebra) + 3.921(Math\ 0990\ Beginning\ Algebra) \\
&\quad +0.882(Gender)
\end{aligned}
$$

Figure 16. Multiple regression equation (attitude posttest)

Table 9

Multiple Regression Analysis Summary (Final Attitude)

	Unstandardized Coefficients		Standardized Coefficients		
Variable	B	SE_B	Beta	t	Sig.
(Constant)	7.927	2.559		3.098	0.002
Content PreTest %	0.023	0.039	0.014	0.589	0.556
Attitude PreTest	0.887	0.023	0.833	38.005	0.000
Class Type (Trad=0, Rev=1)	-2.603	1.639	-0.042	-1.587	0.113
Teacher3	0.638	3.021	0.005	0.211	0.833
Teacher4	6.593	2.570	0.060	2.565	0.011
Teacher5	0.621	2.476	0.006	0.251	0.802
Teacher10	-1.773	2.497	-0.016	-0.710	0.478
Teacher12	-3.171	4.742	-0.014	-0.669	0.504
Teacher13	-2.577	2.377	-0.028	-1.084	0.279
Teacher15	7.893	6.412	0.027	1.231	0.219
Teacher21	-0.488	6.022	-0.002	-0.081	0.935
Teacher23	4.260	2.948	0.035	1.445	0.149
Teacher25	-1.543	2.900	-0.012	-0.532	0.595
Ethnicity=Black or African American	-12.356	3.785	-0.069	-3.265	0.001
Ethnicity=Hispanic	1.951	2.631	0.015	0.741	0.459
Ethnicity=Multiracial	-8.925	3.627	-0.051	-2.461	0.014
Ethnicity=Native Hawaii/Pacific Islander	-2.494	4.178	-0.013	-0.597	0.551
Ethnicity=Non-Resident/Alien	2.383	7.348	0.007	0.324	0.746
Ethnicity=Unknown/Undisclosed	3.055	6.552	0.010	0.466	0.641
Course=Math 0950	4.794	2.775	0.048	1.728	0.084
Course=Math 0990	3.921	1.592	0.070	2.462	0.014
Gender (Female=0, Male=1)	0.882	1.256	0.016	0.703	0.483

Dependent Variable: Attitude PostTest

A significance level of .05 was used for all regression variables. Thus, there is a 5% chance of making a Type I Error (i.e. rejecting the null hypothesis erroneously).

Neither the class type ($p = 0.113$) nor the content pretest scores ($p = 0.556$) had a significant impact on the attitude posttest scores. However, the attitude pretest scores ($p < .001$) did significantly impact attitude posttest scores; however, the coefficient of 0.887 indicated that the impact was less than 1 point out of 160 possible points.

Of the 26 teachers in the database, 14 teachers opted not to administer the content or attitude pretests or posttests in their classes. Thus, these teachers were removed from the analysis. One teacher also showed a very strong correlation with the class type variable and needed to be removed from the analysis. Of the remaining teachers, there was only one teacher ($p = .011$) that significantly impacted attitude posttest scores. The coefficient for this teacher suggests that attitude posttest scores may be affected by as much as 6 points (out of 160). However, overall teachers had minimal influence on the final attitude of students.

The White/Caucasian ethnicity served as the reference category for the ethnicity variables. Black or African American students ($p = .001$) performed significantly lower (by about 12 points) on the attitude posttest than the White/Caucasian students. Multiracial students ($p = .014$) also performed significantly lower (by about 9 points) on the attitude posttest than the White/Caucasian students. With $p = .014$, Math 0990 (Beginning Algebra) students performed significantly higher (by about 4 points) than the Math 1010 (Intermediate Algebra) students on the attitude posttest. With $p = .483$, gender (i.e. Male or Female) also did not significantly impact attitude posttest scores.

Qualitative integration. In the quantitative analysis, only one of the 12 teachers had a significant impact on the final student attitude, suggesting that most teachers had minimal influence on the final student attitude. The thematic analysis of the interview data supports this conclusion as very few of the interviewed students indicated that their professor was a determining factor in their attitude towards the class or math in general. Two interviewees indicated a positive emotional connection to the professor. Abby (personal communication, January 17, 2017) stated "The professor was awesome," and Don (personal communication, January 31, 2017) stated "My teacher was really awesome." Still the interviews did identify several factors tied to student attitude. The Qualitative Analysis & Results section under Research Question 3 contains more details.

Research Question 3

How do students describe their experiences, attitudes, and content knowledge acquisition while participating in the revised and the traditional developmental mathematics programs at one community college in the Western United States?

Qualitative analysis & results. The interview questions themselves served as the broad thematic categories used for the qualitative analysis of the interview data. These thematic categories included reasons for taking developmental math courses, class description, elements that helped learning, elements that hindered learning, level of content mastery, projects, emotions and attitudes associated with experiences, how experiences changed attitude, and suggestions to improve student experiences and learning. After I coded student comments according to these main thematic categories, I then looked more closely at the finer points made by each interviewee to find emergent patterns and trends. The main threads used to explain these emergent patterns included class type and academic achievement level. This section presents these emergent themes and trends organized by interview question.

Note that all interviewee names used are pseudonyms. There were two interviewed students in each of the six groups (3 performance level groups for the revised courses and 3 performance level groups for the traditional courses). The performance levels were: (1) students who performed exceptionally well in each developmental math courses taken; (2) students who demonstrated average performance in most developmental math courses taken; and (3) students who showed significant struggles in completing their developmental math program. More information on the interviewee groups appears in the Qualitative Data Collection and Analysis subsection in the Research Design and Rationale section of Chapter 3. Aaron and Abby were in revised group 1, Bill and Brittany were in traditional group 1, Carla and Cindy were in revised group 2. Debbie and Don were in traditional group 2, Erik and Evan were in revised group 3, and Faye and Fred were in traditional group 3.

Reasons for taking developmental math courses. The reasons that students took developmental math courses were fairly consistent across all the interviewee groups. The interviewed students most commonly took the courses because they were required due to placement tests or for prerequisites for other courses needed to complete their programs of study. Table 10 shows specific quotations of interviewees confirming this assertion. The next most common reason given for taking the developmental math courses was to fill gaps in math content knowledge. Table 11 shows some interviewee comments indicating this as a key reason for taking developmental math courses.

Table 10

Interviewee Comments: Developmental Math Was Required

Interviewee Name (Pseudonyms)	**Responses the Prompt** *Describe your reasons for taking developmental math courses.*
(Bill, personal communication, January 14, 2017)	"I took 1010 because I had tested into it. I needed to eventually take Trig so that I could take Physics so that I could have that dental prerequisite done. "
(Brittany, personal communication, January 20, 2017)	"I had to take them…Prerec requirements…"
(Cindy, personal communication, February 27, 2017)	"I took them because I had to if I was going to get my associates."
(Debbie, personal communication, February 11, 2017)	"I had to take two math classes, and since I didn't have any AP math credits or anything like that, I had to take 1010 in order for the credits to count. And then I would have to take a 1020 through 1050 to graduate."
(Erik, personal communication, January 28, 2017)	"It was just a required class to get my degree."
(Evan, personal communication, January 17, 2017)	"Because I had to."
(Fred, personal communication, January 23, 2017)	"Because I needed to take them…I couldn't get an associate's if I didn't have those."

Table 11

Interviewee Comments: Need to Fill Knowledge Gaps

Interviewee Name (Pseudonyms)	**Responses the Prompt** *Describe your reasons for taking developmental math courses.*
(Abby, personal communication, January 17, 2017)	"I thought I should start at the beginning…So ya, that's why...to fill a big gap."
(Cindy, personal communication, February 27, 2017)	"Are you asking why I was taking a lower level of math? If so, it's because I've always struggled with math."
(Don, personal communication, January 31, 2017)	"I'm not really very good at math."
(Fred, personal communication, January 23, 2017)	"Well I was without math for a year after I ended high school, and I just felt like I needed a good base to kick off from…you know, to get back into the habit of doing math again…and just not jumping in too deep and getting in over my head."

Additionally, Carla (personal communication, January 17, 2017) indicated that she took the revised developmental math courses because the ability to complete content at her own pace helped meet her learning needs. She specifically said:

> I remember that the difficulty I had most in math was I couldn't grasp concepts as fast as the other students. And so in a typical classroom setting, it moved too fast for me. Where the options offered at [the participating college] allowed me to move at my own pace."

Along similar lines, Abby (personal communication, January 16, 2017) mentioned that she took the developmental math "to get [her] confidence up."

Faculty and staff also seemed to play a role the decision of students to enter the developmental math program. School counselors helped Fred (personal communication, January 23, 2017) to make his course decisions. He stated, "So I just decided…and from the advice from the counselors…to start out from the beginning and just take it one class at a time, and go from a good solid base and then work our way up." Furthermore, a big draw to the developmental math program for Don (personal communication, January 31, 2017) was a specific teacher that he "heard was really good."

In summary the key reasons that the interviewed students took developmental math courses included to meet academic requirements, fill math knowledge gaps, take advantage of self-pacing learning options, build confidence, follow counselor guidance, and learn from quality teachers.

Class description. The interviewed students who participated in the revised developmental math program mentioned that working on online content and projects were the two main facets of those course. Regarding the online content, Aaron (personal communication, January 16, 2017) also added that "You could always go ahead, and you could …further progress however far you wanted." Furthermore, Abby (personal communication, January 17, 2017) mentioned that "there was an aide, and the professor was always walking around answering any kind of questions." In accord with Abby, Evan (personal communication, January 17, 2017) also stated, "…then if you needed help, you'd raise your hand, and the teacher or the tutor would come by, usually pretty quickly, and help you through whatever you were struggling with." According to Aaron the online content delivery system also "would always do reviews and reviews and reviews…it really just burned into your mind."

Some students in the revised developmental math courses also mentioned that group interaction and collaborations were a big part of the projects and review sessions for the classes. Aaron (personal communication, January 16, 2017) commented, "You'd choose like groups or go by yourself, and you'd do the…kind of look at the worksheet and kind of take what you learned off of the computers and transition it into something entirely different." Carla (personal communication, January 30, 2017) added, "on occasion when we had an upcoming test, we would do a review as a class, or rather a review as a group..."

Most interviewed students that attended the traditional developmental math courses agreed that courses would typically begin with questions from previous content followed by a lecture by the teacher on the new material. Then the students would have homework to complete on the new material. Don (personal communication, January 31, 2017) mentioned that his teacher would also have pairs of students work on problems together, and "then each would have to go up and present it on the board and show how they did it." Bill (personal communication, January 14, 2017) also reported that his professor would often have his class complete review worksheets in class prior to taking an exam.

In summary the revised developmental math courses had students work individually through the online content, assessments, and reviews during class. The professors and tutors were available during this time to answer questions and assist students. They also had occasional projects which often incorporated group interactions and collaborations. The traditional courses typically started with questions pertaining to prior content followed by a lecture on new content. The students would then complete homework on the new content. Some group activities and test reviews also were included in some classes.

Elements that helped learning. Among all the interviewed students, the most common element that benefited learning at all achievement levels and for both class types was the availability of student support both in and out of the classroom. As is evident from the related comments in Table 12, the assistance provided by professors, tutors, or teaching assistance during class was a major factor in helping students learn the material. In addition Don (personal communication, January 31, 2017) and Fred (personal communication, January 23, 2017) both added that they made good use of the tutors in the math lab on campus to help them better learn and understand the material covered in classes. Brittany (personal communication, January 20, 2017) also mentioned that the help options available within an online homework system were also really helpful. Furthermore, Erik (personal communication, January 28, 2017) added that the online assistance and instruction made it so that learning could take place "without needing a professor there with you." A closely related element that helped student learning was the ability of the professor to adapt instruction and support to specific student needs. Aaron and Fred both asserted that it was helpful to learn the material in different ways from the professor.

Table 12

Interviewee Comments: Availability of Student Support

Interviewee Name (Pseudonyms)	**Responses the Prompt** *Which elements of the class helped you most in learning the math content? Why?*
(Aaron, personal communication, January 16, 2017)	"But I could learn it step-by-step and also ask the professor or the T.A. that was there because most of the time it was just one little step I was missing."
(Abby, personal communication, January 17, 2017)	"…there was an aide, and the professor was always walking around answering any kind of questions we had. It was really good. The aides were awesome. The professor was awesome. If people had questions, she'd work problems out on the board."
(Brittany, personal communication, January 20, 2017)	"And so I went to my teacher and got help from her" "…the way that it was set up…our assignments were set up, you could kind of click on helps and stuff, and it would kind of walk you through it. So I think that was really helpful."
(Debbie, personal communication, February 11, 2017)	"And if we had any questions, he would try really hard to answer them. He made a solid effort, I guess. Most of my questions got answered in a way that I could understand them."
(Don, personal communication, January 31, 2017)	"And when it got towards test time, I'd go to the math lab, and I'd sit there and I'd …figure out how to do them properly."
(Erik, personal communication, January 28, 2017)	"Part of the best part is that you would take it home mostly, and if you failed too many times in iLearn, it would go over and break it down and teach you. So if you didn't know what you were doing, sometimes that was really nice to have because it was kind of like instruction without needing a professor there with you."
(Fred, personal communication, January 23, 2017)	"Well I was without math for a year after I ended high school, and I just felt like I needed a good base to kick off from…you know, to get back into the habit of doing math again…and just not jumping in too deep and getting in over my head." "And you could go to the math lab afterwards and go over it."

Having the content or homework available in an online, organized interface also helped student learning. Aaron (personal communication, January 16, 2017) stated, "Honestly, I think it was just … with the iLearn just how it was set up. It was something I could do online…. Then they'd show me step-by-step." Referring to the online homework management system used in her class, Brittany (personal communication, January 20, 2017) added that "it was convenient, you know, when you've got kids." Regarding the convenience of the online content delivery system, Erik (personal communication, January 28, 2017) also asserted that "the best part is that you would take it home."

A few students also mentioned the benefits of working through homework problems repeatedly to help them master the content. Aaron (personal communication, January 16, 2017) stated, "I have to do the problem repetitively until I get it.... I think it was more that it kept reviewing and kept refreshing your mind." Along the same lines, Carla (January 30, 2017) said, "I got lots of practice on specific concepts, which helped it to stick better than it would have just when you're in a class setting." In conjunction with the mastery learning approach in her revised class, Abby (personal communication, January 17, 2017) also found that the ability to "move ahead as fast as [she] wanted to…relieved a lot of stress for [her]." Referring to the online homework system used in her class, Brittany (personal communication, January 20, 2017) also stated, "And you could do as many practice problems as you wanted. So you could do the same one over and over and the same type of problem over and over. And that was helpful."

Only one of the students who participated in the revised developmental math program mentioned that "sometimes the project days were helpful" (Evan, personal communication, January 28, 2017). Where several interviewees mentioned that the projects and associated group interactions were a main part of the revised developmental math courses, the lack of comments regarding the helpfulness of the projects in learning the content is noteworthy. In contrast, two of the traditional students found the group interactions and collaborations within their classes quite helpful. Don (personal communication, January 31, 2017) explained, "And he would tell everybody to group up into groups…and each person do a problem and explain to the group how they did that problem." Don added that these interactions contributed to a "friendly environment" with "everybody helping each other." Fred (personal communication, January 23, 2017) added, "I liked going into the book classes a little bit more because it was more interaction with the professor, and he would let us work as a class."

Last, when asked what elements helped learning in her revised developmental math course, Cindy (personal communication, February 27, 2017) stated, "If I'm being honest, none of it was very helpful. Too fast paced. Time would have been the most helpful element, and there wasn't much of that." This statement suggests that learning barriers for some participating students were too substantial to allow effective learning to take place.

In summary the most helpful element of both the revised and traditional developmental courses was the availability of student support from the professors, tutors, teaching assistants, and online homework systems. The organization and convenience of the online content and homework management systems were also a big help for some students. Opportunities to repetitively work through homework and review problems and work at a personalized pace helped some students master the content better as well. In addition, some of the projects in the revised courses were helpful to one of the students. However, none of the revised math students identified the group interactions associated with many of their projects as being helpful to their learning. Conversely, two of the traditional students listed group interactions and collaborations during their classes as being quite beneficial.

Elements that hindered learning. Although some of the revised developmental math students thought of the online content delivery and homework systems as being helpful to their learning, many also admitted that several elements of the online systems hindered learning. Aaron (personal communication, January 16, 2017) asserted that the online homework system was often inflexible in how answers could be entered. As corroboration of Aaron's assertion, Evan (personal communication, January 17, 2017) stated, "it wanted it done a certain way, and if you went around a different way, it didn't like that. Or like if you mis-clicked a number, it was gone. You were wrong." Furthermore, Erik (personal communication, January 28, 2017) added, "because it's a computer system, it takes exact answers. So sometimes you could get the correct answer but input it incorrectly." Abby (personal communication, January 17, 2017) also found the timeout timer for the online homework problems to be frustrating:

> And also when I was working on a problem, if I didn't know how to work it out…you can go online and you can go to the tutorial for those types of problems, but then you're timed out on that problem. And it will give you a different problem. So that was frustrating.

Another revised student found the lack of adaptive instruction within the online system a barrier to learning: "And the professor can like change how they word things and how they teach it over and over. But with the program, it just gives you the same thing." (Erik, personal communication, January 28, 2017).

One of the most common issues that students had with online system used in the revised courses involved excessive progress delays when trying to master some topics. Aaron (personal communication, January 16, 2017) stated, "I remember there was one section I was stuck in so long…" Abby (personal communication, January 17, 2017) added, "The reviews would go on forever, and you'd finish one review and there would be another review. And I hated that about iLearn." Cindy (personal communication, February, 27, 2017) shared similar concerns:

> Often times I felt that the HW never ended, usually because I got a few questions wrong and had to start over again. By the time I finished one section and understood what was being taught, everyone else in class was two or three sections ahead. So when I went to class I was behind before I even walked through the door.

Erik (personal communication, January 28, 2017) also experienced this struggle with the online system: "And so it was really easy to get stuff wrong. And if you got so many wrong, you would have to go through the entire teaching process again, which was time consuming. And if you knew what you were doing, it was really frustrating."

An additional limitation of note within the revised classes was insufficient group interaction and collaboration. Carla (personal communication, January 30, 2017) noted, "You didn't get the same type of interaction with other students, which meant you didn't get to hear other students' questions or have the teacher explain it." A similar point was made when Erik (personal communication, January 28, 2017) stated, "You don't really build a classroom…for me you don't really feel like the class togetherness thing...it's like you don't really know who they are and you have to do projects with them." Thus, even though several students acknowledged that many of the projects in the revised classes incorporated group work, some students still did not think there were enough group interactions to be truly effective.

Another barrier to learning involved lingering negative attitudes and low self-concept. As evidence of this barrier, Abby (personal communication, January 17, 2017) observed that when she would get bogged down working on content, she would feel tired, exhausted, and a "little negative." Cindy (personal communication, February 27, 2017) further explained:

> If you take out the barrier of time, the only thing left was myself. I felt stupid because I didn't understand the content. Basically, I was holding myself back by negative inner dialogue. When you believe that you're stupid, it kind of comes true in a way.

Erik (personal communication, January 28, 2017) also noted a closely related barrier of insufficient motivation: "…usually anything that motivates me is challenging and responsibility. It's hard to feel responsible to the program…"

In addition to the previously mentioned barriers to learning, pacing was also listed as a learning barrier for students in both the revised and traditional courses. Bill (personal communication, January 14, 2017) pointed out, "I would say that overall when teachers go a little bit too fast over a subject." Cindy made a similar observation:

> I often times felt that the professors felt pressured to teach a certain amount of chapters each week. Because of that, when someone such as myself didn't understand what was being taught, I didn't get the help that I needed to fully understand.

While Debbie (personal communication, February 11, 2017) also thought that content was often taught at an excessively accelerated pace, she also noted that sometimes the pace was "way too slow."

Test anxiety was another barrier to learning shared by struggling students in both the traditional and revised classes. Faye (personal communication, January 25, 2017) mentioned, "Personally for me I just get really bad test anxiety." Furthermore, Erik (personal communication, January 28, 2017) added that the developmental math courses put too much "emphasis on test scores."

Last, the lecture itself often involved learning barriers within the traditional courses. Debbie (personal communication, February 11, 2017) explained, "I can tell you that I did not care for the fact that it used a PowerPoint because that was very mind-numbing and dull." Fred (personal communication, January 23, 2017) also mentioned that he had difficulty "following along a lot of the time." In addition to having similar difficulties following the lecture in class, Faye (personal communication, January 25, 2017) also stated that she always had "a harder time taking notes with math when it's just the lecture class."

In summary the key barriers to learning in the revised developmental math courses included inflexible syntax when entering answers in the online system, excessive delays in mastering some topics, insufficient group interaction and collaboration, low motivation and self-concept. The key barriers to learning unique to the traditional developmental math courses included ineffective lectures, difficulty following along, and difficulty taking notes. Pacing (too fast or too slow) and test anxiety were also barriers to learning shared by students in both the revised and traditional developmental math courses.

Level of content mastery. As noted in the Qualitative Integration subsection under Research Question 1, most students in both class types and in all achievement level groups felt that they had mastered the content fairly well. Table 6 contains supporting interviewee quotations. However, some students did not perceive their level of mastery of the content as being high. For example, Debbie (personal communication, February 11, 2017) expressed uncertainty regarding her level of mastery: "I honestly can't say. If you put an equation in front of me, I'm 75 to 65% sure that I could answer the question correctly. I'm a solid 80% sure I could get it reasonably close." Cindy (personal communication, February 27, 2017) explained, "It was rare that I 'mastered' any of the math topics." Faye (personal communication, January 25, 2017) similarly that she "always felt lost" in her traditional developmental math course.

Projects. Of the 12 interviewees, three of them recalled specific examples of projects completed in their classes. For instance, Abby (personal communication, January 16, 2017) stated, "The one that I thought was really applicable…is the shopping…you know percents and money management stuff." Similarly Cindy (personal communication, February 27, 2017) recalled, "…we went outside to figure out how tall the trees and poles around the building were; something to do with shadows. It was interesting to find out how tall those trees had grown…" Debbie (personal communication, February 11, 2017) also shared:

> …we were doing the security camera thing. Basically it's the museum is laid out and it will give you a rectangle or a parabola or some shape (a star or whatever).

> And it'll say if you'll only place this many cameras, where would you place them to get the maximum amount of video coverage to witness everything.

Some students viewed the projects in a positive light. Aaron (personal communication, January 16, 2017) said, "It really helped with critical thinking outside of class…just not with math class but with a lot of other things…just thinking about things more critically." Along the same lines, Abby (personal communication, January 17, 2017) stated that her professor "always had really good projects that showed that it was applicable to everyday stuff." Although his traditional class did not do projects, Fred (personal communication, January 23, 2017) likewise asserted that stories and career connections embedded in the class lectures helped him and his classmates:

> …the professor would tell stories of how we would apply it in the real world in a sense. He would explain like this is the kind of career this would use, but we didn't really do much as activities or projects or anything like that. I think a lot of us kind of looked into careers because if it was a concept that we mastered really well, we would go look into that career because we felt like we knew the math well enough. Like I have a lot of friends going into engineering because of that class because he would explain what parts of the math engineers would use.

Conversely, there were several students that did not recall doing any projects at all or that avoided the projects entirely. Some also questioned the relevance of the projects. For example, Cindy (personal communication, February 27, 2017) stated, "I didn't find any reason why I would ever pull out my calculator so that I could see how tall something is…" Likewise, in reference to a specific project, Debbie (personal communication, February 11, 2017) stated, "I don't understand how this would help me at all."

In summary only of few of the students interviewed recalled specific projects from their developmental math courses. Of those the remembered the projects, some could see how the project could apply math directly to their daily lives while others had a hard time seeing the relevance of the projects. Furthermore, several students did not do any projects in their classes.

Emotions and attitudes associated with experiences. Most of the students interviewed recalled both positive and negative emotions and attitudes being a part of their developmental math experiences. However, the ratio of positive emotions to negative emotions tended to decrease as performance level and perceived success decreased. From the comments in Table 13, many students experienced satisfaction, accomplishment, and increased confidence when they were able to successfully complete homework and tests with a decent level of mastery. Others showed vague interest (Debbie, personal communication, February 11, 2017) or simply did not hate math as much as they had previously (Carla, personal communication, January 30, 2017). Carla added that she felt like she "was actually learning something," which was not the case for her previous math classes.

Table 13

Interviewee Comments: Positive Emotions and Attitudes

Interviewee Name (Pseudonyms)	**Responses the Prompt** *What emotions and attitudes do you associate most with your experiences in your developmental math courses? Why?*
(Aaron, personal communication, January 16, 2017)	"The rewarding part was seeing a good grade at the end"
(Abby, personal communication, January 17, 2017)	"I had a lot more confidence after." "There's not much greater satisfaction then getting it figured out. 'Oh my gosh, I get it!' At the end I had a lot better attitude about it. Ya. It was good."
(Bill, personal communication, January 14, 2017)	" I felt fairly confident as I would grasp the different subjects" "…when I started taking Math 1010…and I started to do well on the tests and on the different assignments, then [the stress] definitely went down, and it was replaced more with confidence and some satisfaction for sure."
(Brittany, personal communication, January 20, 2017)	"I feel like it was a positive experience. I actually … if I understand math, then I enjoy it." "Some parts I actually kind of liked, which is really weird."
(Carla, personal communication, January 30, 2017)	"Over all it was … I have mostly hated math classes my entire life, but that was the first time I found myself not absolutely hating it." "I felt productive in the class, and I felt like I was actually learning something in that class as opposed to other classes that I had taken."
(Debbie, personal communication, February 11, 2017)	"…it really was vague interest. Like interest in the content but not in the way it was being put forth."
(Don, personal communication, January 31, 2017)	"I was happy that I got through it because I had struggled with math so much. It was still a hard class to do, but I didn't dread it."
(Erik, personal communication, January 28, 2017)	"With stuff that you didn't know and iLearn was able to refreshen your memory and teach you, that was pretty satisfying because it's just like "oh ok that's it", and you're able to do it."
(Evan, personal communication, January 17, 2017)	"Because when … at least for me when I got it, it was like "Oh, I finally get it. It's making sense." And you just like … you know, the rest of the chapter just flew by...And once you got over it, it was a feeling of accomplishment and victory…"

As is evidenced from the comments in Table 14, the most common negative emotions experienced were stress, anxiety, fear, and frustration. These emotions were typically associated with difficulty in mastering content, negative previous experiences learning mathematics, and lack of interest. The anxiety stemmed from various sources, including testing, peer interactions, previous math experiences, and school in general.

In summary most of the interviewed students experienced both positive and negative emotions. The positive emotions were typically tied to moments of success in mastering content while negative emotions were typically connected to a perceived inability to master content or the previous experiences with math and school. Increased student struggles tended to motivate an increase in negative emotions.

Table 14

Interviewee Comments: Negative Emotions and Attitudes

Interviewee Name (Pseudonyms)	**Responses the Prompt** *What emotions and attitudes do you associate most with your experiences in your developmental math courses? Why?*
(Aaron, personal communication, January 16, 2017)	"So some sections it was stressful." "…anxiety with testing…"
(Abby, personal communication, January 17, 2017)	"I had a lot of anxiety about school, and I had to finish everything early. I was always paranoid about giving myself time."
(Bill, personal communication, January 14, 2017)	"I guess initially I felt kind of stressed and overwhelmed"
(Brittany, personal communication, January 20, 2017)	"I remember feeling frustrated because I came into the math lab, and I tried to get help. And they couldn't help me. Anyway, I did get help from my teacher, but it was kind of … I kind of … even then I guess I kind of walked away saying 'I don't fully understand'"
(Cindy, personal communication, February 27, 2017)	"I would have to say that anxiety is the main emotion attached to math. Math has never been my strong suit. Fear has always been acquainted with math, mostly because I'm no good at it."
(Debbie, personal communication, February 11, 2017)	"Boredom. Moments of like severe anger and irritation…mostly towards the people behind me."
(Erik, personal communication, January 28, 2017)	"And if you got so many wrong, you would have to go through the entire teaching process again, which was time consuming. And if you knew what you were doing, it was really frustrating...I just lost motivation."
(Evan, personal communication, January 17, 2017)	"A lot of frustration. You know, you're struggling…and then because you are struggling, it doesn't let you just … it doesn't like it."
(Faye, personal communication, January 25, 2017)	"Just I can't understand any of it. It was just hard to want to do it at all."

How experiences changed attitude. Several interviewed students in the high and average performance groups from the revised and traditional developmental math courses claimed that their level of confidence increased by the time they completed the course. Aaron (personal communication, January 16, 2017) stated, "I realized I could do this. It didn't really matter. I don't have to be a perfect genius at math because I can learn it at my own speed and retain the knowledge." Abby (personal communication, January 17, 2017) had a similar experience: "…it was a really good experience. She completely changed my attitude about it. I had a lot more confidence after." Furthermore, Bill (personal communication, January 14, 2017) also asserted that his confidence increased: "…I realized I can get passed this barrier. I can get to the point where I can do math. And so that was a huge confidence builder for me…" Carla (personal communication, January 30, 2017) also realized that she "really can learn it" with the help of practice and hard work, and as a result "math became more enjoyable." In addition, Don (personal communication, January 31, 2017) explained, "I found out that I didn't suck at math. I just had a difficult time learning math. But once I learned it, I was actually pretty good at it."

As their confidence increased, a few students also noticed that their fear and nervousness decreased. For instance, Abby (personal communication, January 17, 2017) asserted that she began the class with math as her "biggest fear," but after experiencing some success, her attitude changed and she "loved it." Brittany (personal communication, January 20, 2017) added, "I think I felt less nervous going in to my statistics and some of those." Carla (personal communication, January 30, 2017) also observed, "It suddenly wasn't something that was scary and impossible to do."

A couple students also noticed increased perseverance after they realized that they could be successful if they worked at it. For example, Carla (personal communication, January 30, 2017) pointed out that could learn the math content, but she just "had to work harder at" it. Fred (personal communication, January 23, 2017) had a similar realization: I realized I can still do this. I can figure it out if I study hard on it, and I think of it the way that works out best for me, then I can grasp it."

Conversely, two of the students in the average performance group (one revised and one traditional) experienced a decrease in perseverance. As a result of the challenges she faced during her developmental math courses, Cindy (personal communication, February 27, 2017) "ultimately decided to abandon college altogether." …" In addition to decreased perseverance, Cindy also noted "feelings of inferiority" were also a big factor in her decision to abandon college. Similarly, Debbie (personal communication, February 11, 2017) concluded, "This class just made me feel very dull with math and not want to deal with it ever again." Debbie also mentioned that her class "heightened her annoyance" with math in general.

In summary the most common changes in attitude and emotion for both revised and traditional math students in the high and average performance groups included increased confidence, increased perseverance, and decreased fear and nervousness. On the flip side, some of the students who struggled more with the content experienced decreased perseverance as well as more feelings of inferiority and annoyance.

Suggestions to improve student experiences and learning. In order to overcome some of the learning barriers and negative emotions and attitudes experienced in the developmental math courses, the interviewed students had several suggestions for improvement. The main categories for these suggested improvements were changes to the online content and homework system, group interactions and collaborations, strategies to increased engagement and interest during class, test administration, and student support and guidance.

One of the suggested changes to the online content and homework system applied to both the revised and traditional developmental math courses. This suggestion was made by Brittany (personal communication, January 20, 2017) when she stated, "The only thing I can think is maybe have at least optional videos that you can watch when working out the different types of problems." The remaining suggested online content changes applied solely to the revised courses. Firstly, Abby (personal communication, January 17, 2017) suggested, "I would have really loved to have a textbook that accompanied it because it would be nice to be able to look ahead and see what's coming…and to see how to do that problem." In addition, Abby stated that the online problem timers "were too short." Erik (personal communication, January 28, 2017) also would like to add the ability for students to "skip the instruction" for some content, especially when sent back to the instruction for a second time. Evan (personal communication, January 17, 2017) added that when he "got bogged down in…a section" if would have been nice to "just kind of move on" so that he could still learn the remaining material.

Both revised and traditional math students in the average and lower performance groups also recommended that the course include more opportunities to interact and collaborate with the peers. Carla (personal communication, January 30, 2017) noted:

> The biggest one would just be more opportunities to collaborate with others. That was really the only thing. Without that collaboration, it probably took longer to learn the concepts than it would have if I had had the opportunity to talk to other students and work through problems with other students and see how other students thought about the problem and how they figured it out.

In addition, Erik (personal communication, January 28, 2017) suggested that group collaborations be used even when working on the online content:

> I think you could almost be put in groups to do iLearn because I know in class if you have any questions, the first thing you do is ask the teacher, which is great because that's what they're there for and they're the experts. But a lot of times the students can teach each other. And that makes it so you collaborate more, you get to know each other more. Not only that but then also the best way to learn is to teach. Once you're proficient enough that you can teach it, that usually means that you fully understand it.

Faye (personal communication, January 25, 2017) also suggested that opportunities to "test as a group" could be beneficial. Adding to Faye's suggestion, Fred (personal communication, January 23, 2017) mentioned that completing "…practice tests…as a group" was also quite helpful.

Suggestion to increase engagement and interest during class included reviewing material prior to covering it in class, incorporating more interesting projects, and using game-based learning strategies. First, Bill (personal communication, January 14, 2017) asserted that "if you can come to class at least semi-prepared to learn what he is about to teach, then you're much better off." Debbie (personal communication, February 11, 2017) recommended more interesting projects:

> …you can just add new elements…like if you started trying to add some of the 1030 or 1020 elements to the 1010 class…like just to spice it up, so you're not just sitting there like "yes, I know…I learned this already"

Debbie also thought that using some game-based learning approaches would better engage the current generation:

> I think it might be a good idea…what with the way that the current generation is set up…you could find like the older math video games…computer engineers or whatever or programmers…could actually make video games…just as you do the thing, you accomplish goals or something. That might work better…

Test anxiety was also one of the major barriers to learning mentioned by the interviewed students. To help decrease that anxiety, Faye (personal communication, January 25, 2017) recommended that all "math testing…be done in the classroom not at a testing center" because she knew "everyone in the classroom [was] doing the same thing…so it's not as scary." As mentioned previously, Faye also recommended that alternative testing that encouraged group collaboration would also help diminish test anxiety. Fred (personal communication, January 23, 2017) also mentioned that working on reviewing for tests with groups also helped.

The remaining improvement suggestions involved student support and guidance. Cindy (personal communication, February 27, 2017) stated:

> Maybe, math should be tailored to what each student is majoring in more efficiently. I, along with many others, would be better off focusing on more practical math--stuff that we could actually use in our daily lives.

In addition to more practical math pathways, Fred (personal communication, January 23, 2017) also suggested that many students choose more appropriate class types if they better understood their individual learning strengths and weaknesses: "So it's nice to just have the variety where people can just kind of pick and choose what they like. But you've got to figure that out early on…like what's going to work best for you." Evan (personal communication, January 17, 2017) also felt that many students would benefit from working with the "student support services" personnel and tutors on campus.

In summary one student recommended that inclusion of instruction videos for courses. Revised students specifically recommended a textbook to accompany the online content, increased time allowed before online problems timeout, the option to skip content instruction if required to repeat a section, and the option to skip passed material after spending excessive time trying to master it. Many students suggested using more group interaction and collaboration in learning content and in reviewing and taking tests. To increase engagement and interest in class, students recommended looking at material prior to the lecture, incorporating more interesting projects, and integrating game-based learning activities. Suggestions to decrease test anxiety included testing in the regular classroom and alternative testing involving groups. Finally, students recommended developing more focused math pathways, helping students better understand their learning strengths and preferences, and using student support services more often.

Evidence of Trustworthiness

To improve the dependability and credibility of the qualitative analysis, the participating students were given an opportunity to verify the accuracy of summaries and interpretations resulting from their comments, and data triangulation was used through the comparison of the qualitative and quantitative results (Creswell, 2009; Creswell & Plano Clark, 2010; Teddlie & Tashakkori, 2009). Revisions were made as needed based on interviewee recommendations during the member checking phase. The quantitative and qualitative analysis sections under Research Question 1, Research Question 2, and Research Question 3 contain more details on the data triangulation used during the analysis.

In addition, thick descriptions of the research context and setting were used to improve the transferability of findings (Creswell, 2009; Teddlie & Tashakkori, 2009). These detailed descriptions of the participating college, the developmental mathematics program, the participating students, and the surrounding community allows similar colleges to better determine how closely the findings would apply to their specific student populations and their developmental math programs (Teddlie & Tashakkori, 2009). More details regarding the context and setting for this research study can be found in the Study Setting sections of Chapter 3 and Chapter 4.

In order to establish confirmability for the qualitative analysis, I clarified any researcher bias by fully disclosing experiences, perceptions, and prejudices that would influence the research approach and interpretations for the study (Creswell, 2013). Details on issues of researcher bias and measures taken to minimize that bias appear in the Role of the Researcher section of Chapter 3. Also in order to help identify and describe researcher bias, I maintained a reflexive journal while collecting and analyzing the interview data (Teddlie & Tashakkori, 2009). Some excerpts from my reflexive journal can be found in Table 15.

Table 15

Excerpts from Researcher's Reflexive Journal

"While conducting the interviews for the qualitative portion of my dissertation, my biggest concerns were that the students would feel pressure to give certain responses or that they would not provide truthful responses because they knew me. To minimize these issues, I worked very hard during each interview to make sure the interviewee knew that their perceptions and experiences were very important and that they should speak their mind. Also I regularly repeated back my understanding of what they said so that I could make sure that I understood their views properly. The member checking steps that I will do later after the initial analysis and write-up will also help to ensure that the interviewees' views, comments, and experiences are portrayed accurately."

"I worked hard to make sure that participants knew that I was interviewing them in my role as a Ph.D. candidate and not as a professor or representative of Snow College."

"As I have currently conducted 10 of the 12 interviews, I think that these objectives were all achieved and that the students felt comfortable sharing their true experiences and thoughts about the developmental math program. They were candid and provided great insights that will be help guide future revisions of the program."

"One concern that others might have involves the fact that I did teach some of the developmental math courses during the 3-year evaluation of the revised program. However, as I do not have a preference for either the revised or traditional classes, my interactions with the interviewees were unlikely to indicate that I preferred one type of class over the other. I recognize that there are many pros and cons to each approach, and I ultimately just want to figure out ways to revise the program to maximize the success of each student."

"At this point I have conducted all 12 interviews, and I am almost done transcribing them. Reflecting back on the interviewing experience, I have noticed that on some occasions I tended to ask two or three questions back to back before pausing to allow for a response. In most cases the second and third questions were simply asking the same thing in a different way, but I realize in retrospect, that the barrage of questions could be a bit overwhelming for the interviewees. However, the interviewees all responded to the questions well, so I don't think there was any adverse effects. I also noted, while listening to the recordings of the interviews, that I sometimes interjected before an interviewee was completely finished with what they had to say. I worry that on a few instances, this may have kept them from fully explaining their thoughts. Still I think they all shared their main ideas, thoughts, and comments. When I realized this was happening during the interview, I made a point to ask follow-up questions that would encourage them to continue sharing. In addition, there are a few instances on the recordings where I was not able to understand what the interviewees were saying, which forced me to omit those potions. They were very small segments, and I'm pretty confident that the main gist of what was said was not lost, but I must acknowledge that these omissions did take place."

To further improve the confirmability and credibility of the qualitative analysis, data triangulation was used, comparing the qualitative findings with the quantitative findings. This data triangulation strategy further validated results where both the qualitative and quantitative findings agreed. Furthermore, negative cases were also discussed in detail (Creswell, 2013; Patton, 2002; Teddlie & Tashakkori, 2009). The negative case descriptions are woven into the qualitative analysis and integrations sections of Chapter 4. Descriptions of these negative cases as well as discrepant cases added contextual depth to the findings to better identify specific student populations and conditions that account for the different findings (Creswell, 2013).

Finally, I randomly selected two of the interviews after initial coding of all interviews was completed. These randomly selected interviews were then coded again from scratch and compared with the original coding to establish intracoder reliability. The second coding of the first interview matched 90.9% of the first coding. The second coding of the second interview matched 85.3% of the first coding.

Summary

Students in revised courses tended to have final exam scores about 16% lower on average than those in traditional courses. However, most of the students interviewed believed that they had mastered the content fairly well. Thus, students may view content mastery in a more relaxed manner compared with the level of content mastery expected of them in their developmental math classes, or the final exams may not be giving a complete measure of content mastery. Attitude and prior knowledge also significantly influenced final exam performance. Teachers may influence student final exam scores by up to 11%. African American, Hispanic, and Multiracial students tended to score 6 to

10% lower on the final exams than White Caucasian students. PreAlgebra students scored significantly higher (by almost 10%) on the final exams than Intermediate Algebra students. Gender did not significantly impact final exam scores.

Students in the revised courses had significantly higher (though by a small margin) attitude posttest scores than those in traditional courses. Teachers may influence attitude posttest scores by as much as 14 points (out of 160). Multiracial students had significantly higher attitude posttest scores than White Caucasian students. Conversely, Native Hawaiian or Pacific Islander students had significantly lower attitude posttest scores than White Caucasian students. Gender did not significantly impact attitude posttest scores.

Factors the helped student learning for the revised and traditional math students included the availability of student support services, the organization of content, working on similar problems repetitively until mastered, personalized pacing for content completion, project integration, and group interaction and collaboration. Factors that hindered student learning for the revised and traditional math students included inflexible online content and homework management systems, excessive delays in mastering content, insufficient group interaction and collaboration, low motivation and self-concept, and difficulty following and taking notes during lessons. While most students thought they had mastered the content fairly well, one revised and one traditional math student mentioned that they mastered very little content. Many students did not recall doing projects in their classes. Of those that did remember doing projects, some felt that the projects helped them see how to apply mathematics outside of the classroom while others saw little relevance to the projects.

Most students experienced both positive and negative attitudes during the developmental math courses. The positive emotions were typically tied to moments of success in mastering content while negative emotions were typically connected to a perceived inability to master content or the previous experiences with math and school. Increased student struggles tended to motivate an increase in negative emotions. In the developmental math courses, higher performing students tended to experiences increased confidence, increased perseverance, and decreased fear and nervousness while struggling students experienced decreased perseverance as well as feelings of inferiority and annoyance.

Suggestions to improve the developmental math courses included making additional resources (textbooks, instructional videos, etc.) available to students, updating online content delivery system options and syntax, and using more group interactions and collaborations to learn content. To better engage students during class, students recommended looking at material prior to attending to a lesson on that material, incorporating more interesting projects, and integrating game-based learning activities. Suggestions to decrease test anxiety included testing within a familiar environment (i.e. classroom) and using alternative testing involving groups. Finally, students recommended developing of more focused math pathways, helping students better understand their learning strengths and preferences, and using student support services more often.

Chapter 5: Discussion, Conclusions, and Recommendations

The purpose for conducting this mixed methods case study was to discover how a revised developmental math program that integrates online, mastery, and project-based learning has impacted student achievement and attitude compared with a traditional lecture-based curriculum taught at a rural community college. The results indicate that the students in the traditional courses outperformed those in the revised courses on final exams. However, the revised math students demonstrated a more positive attitude towards math than their traditional counterparts. According to interviewed students, key factors that directly impacted student learning in these developmental math classes included the availability of student support services, group interaction and collaboration, self-concept and motivation, flexible content delivery and homework options, curriculum focused on student academic and career paths, and the integration of more interesting project-based and game-based learning activities. This chapter provides more in-depth interpretations of the study's findings. Next, additional details pertaining to the study's limitations and recommendations for future research are presented. Last, the study's implications for positive social change are explained.

Interpretation of Findings

This section includes an interpretation of the results of the analyses for each research question. In addition, explanations are provided for how these results and interpretations contribute to the existing research literature.

Research Question 1

How does the final student content knowledge in revised developmental mathematics courses (integrating online, mastery, and project-based learning) compare with that of students in traditional developmental mathematics courses at one community college in the Western United States?

The results indicated that students in the revised developmental math courses performed significantly lower on their final exams than those students in the traditional courses. However, most of the students interviewed believed that they had mastered the content fairly well. One possible explanation for this discrepancy is that students may view content mastery in a more relaxed manner compared with the level of content mastery expected of them in their developmental math classes. As incorrect perceptions have the potential to hinder future performance and motivation (Kim, Chiu, & Zou, 2010; Wright, 2012), future program revisions could incorporate regular self-calibration training activities during classes (Ramdass & Zimmerman, 2008). These activities provide students with the opportunity to self-assess how well they will solve a problem and then compare their self-assessment with their actual performance after they complete the problem.

Another explanation of the discrepancy between final exam performance and student perception of content mastery could be that the final exam is not providing the complete picture of a student's content mastery. Additional alternative assessments may be needed to fully gauge how well students mastered the content. According to Öztürk and Şahin (2014), alternative assessment and evaluation strategies can improve student attitude and achievement mathematics coursework. Interviewed students recommended using group interactions and collaborations more in class and on assessments to resolve this disconnect between content mastery measured by a traditional formative assessment like the final exam and students' perceived content mastery. Test anxiety was also mentioned as a major barrier to learning, which could be adversely affecting student test results. Actively recognizing and addressing test anxiety is critical to resolve this issue. One student observed that the location in which a test is administered could be a trigger for test anxiety. She recommended administering tests in a familiar environment (i.e. the regular classroom) rather than in a less familiar location like a testing center.

The results also indicated that the attitude with which a student began a course also had a significant impact on their final exam scores at the end of the course. These results support the findings of Hemmings et al. (2011) which also indicated that attitude predicted the math performance of students. However, Hemmings et al. found that attitude was a strong predictor of performance whereas this study found that attitude impacted final exam scores by only a small amount. In addition, although Ma and Xu (2004) found that achievement influences attitude more than attitude influences achievement, this study found the opposite to be true (attitude influenced achievement more than achievement influenced attitude). Still this study along with previous research indicates that a student's attitude towards mathematics and performance in a math course are closely connected. Furthermore, students interviewed in this study also observed that as they experienced success in class, their motivation and attitudes increased. Conversely, students whose failures and struggles outnumbered successes tended to have less motivation and more negative attitudes. Therefore, developmental math program revisions must integrate measures to improve both attitude and achievement for students to find the greatest success.

While some teachers in the analysis exhibited a significant impact on final exam scores, there were many teachers that had to be excluded from the analysis because these teachers opted not to administer all of the pretests and posttests in some of their classes. These exclusions greatly limited any inferences that could be made regarding the impact of teachers on final exam scores. However, the coefficients of the teachers who did significantly impact the final exam scores suggest that teachers do have the potential to impact student performance on the final exam by as much as 11%. In addition, the large fluctuation in the coefficients of the teachers in the model suggests that there is a great deal of variability in the effects that individual teachers have on student performance. Although experience, demeanor, and student interactions all likely play a role, additional research (preferably a true experiment that ensures that all data is acquired from all participating teachers) is critical to more fully understand the effects of teachers on student performance.

According to Mosca et al. (2010) and Spradlin (2009), student success in both online students and traditional students can be hindered by struggles with class interactions and motivation. Xu and Jaggar (2013a, 2013b) arrived at similar conclusions but also added that ethnicity could also be a critical factor in student success. Specifically, Xu and Jaggar found that Black students tended to struggle more than other students. This study also found that African American students tended to have significantly lower final exam scores than White Caucasian students. In addition, this study added that Hispanic and Multiracial students also performed significantly lower on their final exams than White Caucasian students. Additional research is also needed to determine what learning barriers are hindering success for the African American, Hispanic, and Multiracial students.

Research Question 2

How does the final student attitude towards mathematics in revised developmental mathematics courses (integrating online, mastery, and project-based learning) compare with that of students in traditional developmental mathematics courses at one community college in the Western United States?

Recall that a major premise of the attributional theory of achievement motivation and emotion was that motivation and persistence depends upon the perceived causes of an outcome and expectancy of future success (Bandura, 1977; Cortes-Suarez & Sandiford, 2008; Locklear, 2012; Weiner, 1985). Thus, as the results indicated that class type (revised or traditional) had no significant impact on final student attitude, qualitative interviews provide more information on this issue. According to the interviewed students, students (from both the revised and traditional groups) who experienced more positive attitudes were able to attribute controllable causes (like effort) as the reason for their performance outcomes (Cortes-Suarez & Sandiford, 2008; Dasinger, 2013). As a result, these students took steps to improve their effort and thus improve their performance outcomes. Conversely, some students in both groups exhibited decreased motivation and persistence as a result of repeated failures and negative emotions. Therefore, as was concluded in the interpretations of findings under research question 1, developmental math program revisions must integrate measures to improve student attitude and help students to better perceive the causes of their success and failure in class as controllable.

The results indicated that attitude pretest scores did significantly impact attitude posttest scores. Furthermore, the analysis indicated that the attitude with which a student began a course had a strong, positive correlation to the attitude at the conclusion of the course. Thus, a student who started the course with a positive attitude was likely to finish the course with a positive attitude, and a student who started the course with a negative attitude was likely to finish the course with a negative attitude. Therefore, improving the attitude of a student who began the course with a negative attitude appears to be a challenging undertaking. But efforts to promote more positive attitudes towards math, especially among students with mainly negative emotions tied to their prior math experiences, is critical to improve self-concept, decrease anxiety, and reduce dropout rates (Cordes, 2014; Cortes-Suarez & Sandiford, 2008; Dasinger, 2013; Feldman et al., 2014).

While one teacher in the analysis exhibited a significant impact on attitude posttest scores, there were many teachers that had to be excluded from the analysis mainly due to missing data from these teachers in the database. These exclusions greatly limited any inferences that could be made regarding the impact of teachers on final student attitude. However, the coefficient of the teacher who did significantly impact the attitude posttest scores suggests that teachers do have the potential to impact student performance on the attitude posttest by as much as 6 points (out of 160). In addition, the large fluctuation in the coefficients of the teachers in the model suggests that there is a great deal of variability in the effects that individual teachers have on student attitude. Although experience, demeanor, and student interactions all likely play a role, additional research (preferably a true experiment that ensures that all data is acquired from all participating teachers) is critical to more fully understand the effects of teachers on student attitude.

Xu and Jaggar (2013a, 2013b) found that ethnicity could be a critical factor in student success. This study extended these previous research findings by adding that ethnicity could also be a critical factor in student attitude. In particular, this study found that Black or African American and Multiracial students had more negative attitudes toward mathematics than White Caucasian students. However, as this effect exists independent of the class type, further research is needed to determine the actual impact that ethnicity plays on student success and attitude within developmental math programs. Furthermore, additional research is needed to determine what learning barriers are stirring up negative feelings for students from these two ethnic groups.

Although Arslan et al. (2012) and Hemmings et al. (2011) found that gender influenced attitude, the results of this study indicated that gender had no significant impact on the final content knowledge or the final attitude of students. Ma and Xu (2004) also concluded that gender did not influence attitude.

Research Question 3

How do students describe their experiences, attitudes, and content knowledge acquisition while participating in the revised and the traditional developmental mathematics programs at one community college in the Western United States?

The availability and effective use of quality student support services are among the most critical factors that impact student learning (Doering & Veletsianos, 2008; Kaifi et al., 2009; Kim et al., 20014; Wickersham & McElhany, 2010). Whether they participated in the revised or the traditional developmental math courses, students interviewed in my study also listed available student support as a major element that helped learning. Therefore, any program revisions should include a thorough student support structure.

This study also indicated that online and mastery-based courses needed to have a clear, easy-to-follow structure and organization in order to promote student learning. This conclusion also supports previous research (Armstrong, 2011; Baran, 2011; Black, 1980; Foshee, 2013; Furner & Gonzalez-DeHass, 2011; Jackson et al., 2010; Xu & Jaggars, 2013a). Thus, care must be taken to structure and organize content when designing or revising developmental math programs.

In addition, previous research found that sufficient time, effort, and resources are required for students to successfully master content (Bloom, 1976; Carroll, 1963; Guskey, 2007; Slavin, 1987). In support of this research, several students mentioned that repeatedly doing homework problems in conjunction with student support (i.e. from professors, tutors, and campus student support services) did help them to master the material well. However, in several cases, excessive delays attempting to master some topics were counter-productive for students, leading to decreased motivation and negative attitudes. Frick et al. (2011) found these negative emotions to often be a result of mastery-based learning curricula. Therefore, a careful balance is necessary to provide students with the time required to effectively master content while also providing support and options for students who are struggling excessively with certain topics.

Another factor that significantly impacted student learning, especially for who struggled to understand and master the material, involved the quantity and quality of peer interactions and collaborations. Athens (2011), Verma et al. (2011), and Weinstein (2004) all found that student success depended a great deal on group interactions and collaborations. This study also found peer interactions to play a key role in student learning. Students recommended using more frequent peer interactions and collaborations while learning the content, while reviewing the content, and even during some assessments on the content. Erik (personal communication, January 28, 2017) commented:

> But a lot of times the students can teach each other. And that makes it so you collaborate more, you get to know each other more. Not only that but then also the best way to learn is to teach. Once you're proficient enough that you can teach it, that usually means that you fully understand it.

According to Foutz et al. (2012), integrating projects into a curriculum can increase student engagement and satisfaction. Thus, the participating college had integrated projects as a key element in their revised developmental math program. However, it was surprising to find that very few students even recalled doing projects in their classes, and of those that recalled doing projects, only one student mentioned that some of the projects were beneficial. Students also indicated that the projects occurred too infrequently for students to benefit from it. In addition, some students felt that the projects needed to be more applicable and relevant to their lives outside of the classroom. Last, one student mentioned that more frequent group interactions during the other facets of the classes would have helped improve the effectiveness of the collaborations used during many of the projects.

Additional noteworthy student suggestions that could improve the developmental math course at the participating college included creating additional resources (like textbooks and instructional videos) to accompany online content, integrating game-based learning strategies to engage the younger generation of students, developing more focused math pathways for students to complete their developmental math program more efficiently, and helping students better understand their learning strengths and preferences.

Limitations of the Study

In Chapter 1, I described several key limitations to this study. As this study used secondary data for the quantitative analyses, I had no control over what data was collected or how that data was collected. Thus, I was limited to a quasi-experimental design. However, as a full-time faculty member at the participating college, the use of archived data also allowed me to more ethically conduct my research. In addition, the qualitative interviews for this study took place approximately 2 years after the participating students completed their developmental math coursework. Thus, accurately recalling experiences was a major limitation. However, this delay between developmental math program completion and the interviews further ensured that I was not able to influence past, present, or future grades for the students. More information on these limitations appear in the Limitations section of Chapter 1.

Another critical limitation to this study involved the need to remove a large number of student records from the analysis because data for some of the variables was missing. Several teachers could not be included in the regression models as well for the same reason. Although the sample sizes used for the models were still quite large, the excluded cases could have significantly altered the model. More specifically, the missing cases may have introduced bias into the analysis because the cases used may not be representative of the actual population, and the results may be overestimated or underestimated (Acock, 2005). Furthermore, the teachers used in the analysis may not have been representative of the actual teacher population as about half of the participating teachers were excluded from the analysis due their failure to administer content or attitude pretests and posttests in some or all of their classes. Thus, in order to confirm the results of this study and better gauge the impact of teachers on student achievement and attitude, future research needs to be conducted that utilizes a true experimental design to better control the data collection from all participating teachers.

Recommendations for Future Research

One way to remedy many of the limitations posed on this study is to replicate the study using a true experiment for the quantitative portion. A true experiment will provide the researcher with the requisite control over the implementation and data collection phases of the research. As a result validity and generalizability of the findings will increase a great deal. This true experimental design would also allow a more complete set of data from all participating teachers so that the impact of the teachers themselves can more conclusively be determined. Besides using a true experimental design, other ways to increase the validity and generalizability of the results include studying the impact of a similar developmental math curriculum on student populations from various colleges and universities in both rural and urban settings.

In addition to exploring the influence of traditional and revised developmental math curricula on student learning and attitude, other factors that influence performance and attitude were also discovered in this study. Firstly, African American, Hispanic, and Multiracial students exhibited significantly lower final content knowledge than White Caucasian students. In addition, Hawaiian or Pacific Islander students exhibited significantly lower final attitudes toward mathematics than their White Caucasian counterparts. Multiracial students also showed a significantly higher attitude towards math in spite of their lower academic performance. Each of these ethnicities should be targeted in future studies to determine what factors are most helpful in promoting learning and what factors serve as the greatest barriers to their success. Such research will motivate a multicultural approach to program revisions which will aid even more students in those programs.

Another important element that should be better explored in future research involves the integration of projects into the developmental math curriculum. The math department at the college participating in this study chose to combine projects with their adopted online, mastery-based content delivery system in order to increase student engagement and satisfaction. However, the projects did not seem to have the desired effect on the participating students. Therefore, future research should utilize and improved curriculum that incorporates more relevant projects in conjunction with additional strategies to improve group interaction and collaboration. The more frequent projects and additional experience working together with peers will likely improve student success based on the suggestions of the students interviewed for the current study. In addition, developing an identical set of projects to be implemented by all participating teachers would also help future research to better isolate the impact of the projects on student success. These projects could also incorporate game-based learning approaches to better engage the younger generation of students.

Implications for Social Change

This study will motivate positive social changes as the results assist the participating college and other colleges with similar demographics to make crucial decisions that will improve the success of their developmental math programs. Furthermore, the resulting program revisions will nurture more positive student attitudes towards mathematics, will help increase student confidence in their abilities to succeed, and will motivate students to persist in their education and complete their program of study. These students will then be better equipped and driven to make positive contributions to their future communities and workplaces.

Conclusion

The results of this mixed methods study indicate that students in traditional developmental math courses exhibited higher final content knowledge than those students in the revised developmental math course. However, as both revised and traditional math students claimed to have mastered the content fairly well, there may be need for additional alternative assessment measures to more clearly paint the picture of content mastery within those programs. Furthermore, this study found that student attitude significantly impacted content knowledge while content knowledge did not significantly impact student attitude. Thus, in accord with Weiner's (1985) attributional theory of achievement motivation and emotion, there are complex interactions that exist between the achievement and attitudes of developmental mathematics students. Furthermore, additional factors (i.e. student ethnicity, teachers, student support, and student collaboration) also influence the success and attitude of developmental math students. Future research should explore each of these factors more thoroughly to identify the best combination of elements that promote the greatest student success in a variety of college settings. Then as colleges continue to improve their developmental math programs based upon this growing pool of quality research, participating students will develop more positive attitudes toward mathematics and will also experience greater academic success. They will then be better equipped to positively contribute to their future communities and workplaces.

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Appendix A

Attitudes Toward Mathematics Inventory (ATMI)

ATTITUDES TOWARD MATHEMATICS INVENTORY

Name ____________________________ *School* _____________________________

Teacher ____________________________

Directions: This inventory consists of statements about your attitude toward mathematics. There are no correct or incorrect responses. Read each item carefully. Please think about how you feel about each item. Enter the letter that most closely corresponds to how each statement best describes your feelings. Please answer every question.

PLEASE USE THESE RESPONSE CODES:

A – Strongly Disagree
B – Disagree
C – Neutral
D – Agree
E – Strongly Agree

1.	Mathematics is a very worthwhile and necessary subject.	
2.	I want to develop my mathematical skills.	
3.	I get a great deal of satisfaction out of solving a mathematics problem.	
4.	Mathematics helps develop the mind and teaches a person to think.	
5.	Mathematics is important in everyday life.	
6.	Mathematics is one of the most important subjects for people to study.	
7.	High school math courses would be very helpful no matter what I decide to study.	
8.	I can think of many ways that I use math outside of school.	
9.	Mathematics is one of my most dreaded subjects.	
10.	My mind goes blank and I am unable to think clearly when working with mathematics.	
11.	Studying mathematics makes me feel nervous.	
12.	Mathematics makes me feel uncomfortable.	
13.	I am always under a terrible strain in a math class.	
14.	When I hear the word mathematics, I have a feeling of dislike.	
15.	It makes me nervous to even think about having to do a mathematics problem.	
16.	Mathematics does not scare me at all.	
17.	I have a lot of self-confidence when it comes to mathematics.	
18.	I am able to solve mathematics problems without too much difficulty.	
19.	I expect to do fairly well in any math class I take.	
20.	I am always confused in my mathematics class.	
21.	I feel a sense of insecurity when attempting mathematics.	
22.	I learn mathematics easily.	
23.	I am confident that I could learn advanced mathematics.	
24.	I have usually enjoyed studying mathematics in school.	
25.	Mathematics is dull and boring.	
26.	I like to solve new problems in mathematics.	
27.	I would prefer to do an assignment in math than to write an essay.	
28.	I would like to avoid using mathematics in college.	
29.	I really like mathematics.	
30.	I am happier in a math class than in any other class.	
31.	Mathematics is a very interesting subject.	
32.	I am willing to take more than the required amount of mathematics.	
33.	I plan to take as much mathematics as I can during my education.	
34.	The challenge of math appeals to me.	
35.	I think studying advanced mathematics is useful.	
36.	I believe studying math helps me with problem solving in other areas.	
37.	I am comfortable expressing my own ideas on how to look for solutions to a difficult problem in math.	
38.	I am comfortable answering questions in math class.	
39.	A strong math background could help me in my professional life.	
40.	I believe I am good at solving math problems.	

Documentation Granting Permission to Use ATMI

RE: permission request to use Attitudes Toward Mathematics Inventory...

Tapia, Martha [mtapia@berry.edu]
Sent: Wednesday, January 15, 2014 9:43 PM
To: Steve Zollinger

Dear Steve,

You have permission to use the Attitudes Toward Mathematics Inventory (ATMI) in your dissertation. If you have any question, please do not hesitate to ask me.
Please let me know of the findings in your study.

Sincerely,

Martha Tapia

Martha Tapia, Ph.D.
Associate Professor
Department of Mathematics and Computer Science
Berry College
P.O. Box 495014
Mount. Berry, Georgia 30149-5014

From: Steve Zollinger [Steve.Zollinger@snow.edu]
Sent: Monday, November 25, 2013 5:49 PM
To: Tapia, Martha
Subject: permission request to use Attitudes Toward Mathematics Inventory...

Hello, Dr. Tapia.

I am in charge of the evaluation of a revised developmental math program at Snow College. As part of this evaluation, we would like to assess change in student attitude. May we use the Attitudes Toward Mathematics Inventory (ATMI) for this purpose? If so, please let me know if you have any stipulations for its use. I would also like to use the gathered data from the math department along with other data for my dissertation. May I include the ATMI as an appendix in my dissertation and related documents (i.e. prospectus, proposal, etc.).

Thank you so much for your time and consideration.

Have a wonderful day!

Best Regards,

Steve

Steve Zollinger
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Snow College
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http://www.snow.edu/stevez

Appendix B

Interview Informed Consent Form

You are invited to participate in an interview for a study which will explore the impact of the developmental mathematics program at Snow College on student learning and attitude. Even though I am a faculty member at Snow College, I am conducting this research for my Ph.D. dissertation at Walden University and not as a representative of Snow College.

I am inviting you to be interviewed because of your experiences and insights as a student within this developmental math program. Your thoughts and contributions during this interview will better inform my study and will help me to paint a more vivid picture of how the program truly influenced your learning and attitude towards mathematics. This form is part of a process called "informed consent" that allows you to understand the purpose of the interview before you decide whether or not to take part.

Background Information:
The purpose of my dissertation study is to determine the impact of the revised developmental mathematics program compared with the traditional lecture-based developmental mathematics program at Snow College.

Procedures:
If you agree to be interviewed, you will allow me to interview you for approximately 30-40 minutes. Our discussion will be audio recorded to help me accurately capture your insights in your own words. My dissertation committee and I are the only individuals who may listen to recording of the interview. Once the interview transcript has been transcribed, coded, and thematically analyzed, you will be given the opportunity to check any interpretations and conclusions that were based off of your comments to ensure that your views are being accurately portrayed and that your privacy and confidentiality has been maintained. These post-interview checking and validation procedures may require an additional 30-40 minutes of your time.

Here are the questions and prompts for the interview:

1. Describe your reasons for taking developmental math courses.
2. Describe a typical class session for your courses.
3. Which elements of the class helped you most in learning the math content? Why?
4. Which elements of the class were barriers to your learning? Why?
5. Describe how well you were able to master the math topics taught in your developmental math courses.
6. Describe any projects, activities, or experiences from your developmental math classes that helped you to better understand how the math learned could be useful

outside of the classroom or to gain a greater appreciation for mathematics and learning.

7. What emotions and attitudes do you associate most with your experiences in your developmental math courses? Why?
8. How did your experiences in your developmental math courses influence or change your attitude towards mathematics and learning?
9. What suggestions do you have that could improve student experiences and learning within the developmental math courses?

Risks and Benefits of Being in the Study:

Your participation in this interview will not influence your past, present, or future grades or academic standing at Snow College in any way. However, participating in an interview may be fatiguing or may stir up negative emotions as you reflect on your experiences in the developmental math program at Snow College. If you experience any discomfort or adverse effects from the interview or simply do not wish to continue, you may elect to not answer any question or to withdraw from the interview entirely at any time.

With regard to potential benefits of being in this study, your contributions to this study will help to better identify and understand the elements of the developmental math program that have a positive and negative influence on student learning and attitude towards mathematics. These critical insights will then help drive program revisions to improve student success.

No gifts, compensation, or reimbursements will be provided to you for your participation in this study.

Privacy:
Every effort will be taken to ensure that the information you provide during the interview will be kept confidential. In particular, I will not use your real name when I reference your comments in my dissertation. In addition, you will be given the opportunity to review citations of the interview used in my dissertation in order to ensure that your thoughts, opinions, and comments are being represented accurately. However, if during the course of the interview you disclose having committed a crime or being victim of a crime, I will be ethically and legally obligated to break confidentiality and to immediately notify authorities of these disclosed incident(s).

Contacts and Questions:
You are welcome to ask me any questions that you have about the interview or my dissertation study. You may contact me by cell at 435-813-2671 or by email at steven.zollinger@waldenu.edu. If you want to talk privately about our interview and your rights as participants, you may contact Dr. Leilani Endicott by email at

irb@waldenu.edu. Walden University's approval number for this study is 11-21-16-0288396 and it expires November 20, 2017.

I will provide you with a copy of this consent form for your records.

Statement of Consent:

I have read the above information, and I feel I understand the purpose of the interview well enough to make a decision about my involvement. By signing below, I understand that I am agreeing to the terms described above.

Participant Signature:

____