

THE MATHEMATICS EMPORIUM: INFUSION OF INSTRUCTIONAL TECHNOLOGY
INTO COLLEGE LEVEL MATHEMATICS AND PSYCHOSOCIAL
FACTORS OF LEARNING

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ABSTRACT

This manuscript-based (European style) dissertation consisted of three different, but conceptually related manuscripts. The series of manuscripts examined psychosocial factors of learning including attitude towards mathematics, motivation to learn mathematics, and satisfaction from the mathematics instruction in both redesigned and traditionally- taught college algebra courses at one of the Midwest research universities. This was a quantitative research study that used various statistical methods including exploratory factor analysis, internal replicability analysis, paired-samples t-tests, hierarchical multiple regression analysis, reliability and validity statistics.

The first manuscript was an inclusive literature review that focused on course redesign—mathematics Emporium—and infusion of instructional and learning technologies into college algebra. The second manuscript focused on developing a new inventory to measure students' attitudes toward mathematics, motivation to learn mathematics, and satisfaction from the instructional practices specifically in a technology-supported mathematics education context. It focused on the psychometric properties—validity and reliability—of the Psychosocial Factors of Learning in Redesigned Introductory College Mathematics (PFL-RICM) scale.

The third manuscript examined changes in psychosocial factors of learning not only in the redesigned context, but also in the traditionally-taught college algebra settings. Results of

comparative analyses revealed that learners' attitudes toward technology-supported mathematics, and overall attitudes toward mathematics changed negatively in both traditionally taught and redesigned college algebra over the course of the semester. In traditionally-taught college algebra, beliefs about learning mathematics also changed significantly, but changes in learner motivation and satisfaction were not statistically significant. Attitude toward mathematics, extrinsic motivation to learn mathematics, satisfaction from technology-supported mathematics, satisfaction from instructional design and overall satisfaction of learners from college algebra changed significantly in redesigned college algebra settings. Between group comparisons resulted in significant differences on students' attitudes toward mathematics, and attitudes toward technology-supported mathematics. Learners who enrolled in traditionally-taught college algebra had higher attitudes toward mathematics scores, whereas learners who enrolled in redesigned college algebra had higher attitudes toward technology-supported mathematics.

APPROVAL PAGE

The faculty listed below, appointed by the Dean of the School of Graduate Studies have examined a dissertation titled “The Mathematics Emporium: Infusion of Instructional Technology into College Level Mathematics and Psychosocial Factors of Learning,” presented by Erdem Demiroz, candidate for the Doctor of Philosophy degree, and certify that in their opinion it is worthy of acceptance.

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To my children, Zehra Derin and Toprak Deniz

CHAPTER 1

INTRODUCTION

College algebra, one of the introductory-level mathematics courses that is taught nationwide in mathematics and statistics departments at four-year colleges and universities, and in mathematics programs at two-year colleges, is a bleeding wound of college level mathematics education because of high enrollment rates, low academic achievement and low retention rates. It is estimated that annually 1.2 million students enroll in college-level introductory mathematics courses nationwide, and approximately 650,000 to 700,000 students enroll in a course titled “College Algebra” (Blair, Kirkman, & Maxwell, 2013; Haver et al., 2007). For many students, college algebra is a prerequisite for an advanced college level course or is a requirement for graduation (Barker, Bressoud, Epp, Ganter, Haver, & Pollatsek, 2004). Approximately half of the students who enroll in college algebra sections fail or withdraw, and a significant percent of them need to reenroll in college algebra to satisfy the aforementioned requirements (Benford & Gess-Newsome, 2006; Brewer & Becker, 2010; Gordon, 2008; Haver et al.; Herriott, 2006; Mayes, 2004). These ever persistent problems of college algebra are generally attributed to the content that does not satisfy the mathematical needs of learners and society, that ignores changing student demographics and expectations, that disregards students’ lack of mathematical preparation, that uses ineffective teaching methods, and persists with ill-structured instruction, etc. (Barker et al.; Edwards, 2011; Gordon, 2004, 2008, 2013; Mayes). For many years, remedial efforts such as intensity models, redesigned curricula, project-based and contextual learning, acceleration models, and technology integration have targeted at least one of these reasons to increase the quality of student learning outcomes in college algebra (Alexander, 1996; Berryman & Short, 2010; Epper & Baker, 2009; Lazari, 2007).

A new trend in remediating college algebra for better student outcomes is a course redesign approach which is supported and guided by the National Center for Academic Transformation (NCAT). NCAT is a dedicated non-profit organization that aims to increase students' academic achievement, to increase retention rates, and to reduce the cost of instruction by utilizing instructional and learning technologies. The courses which redesign models focus on usually suffer from high enrollment rates, low academic achievement, low retention rates, and inflated cost of instruction (NCAT, 2015g). Nationwide, the course redesign models of NCAT — namely the supplemental model, the replacement model, the linked workshop model, the buffet model, the fully online model, and the Emporium model — affect approximately 250,000 students annually (NCAT). Among the six different course redesign models, the Emporium model has resulted in the best learning outcomes and cost-savings in college-level mathematics courses. This is one of the main reasons why “Urban U” which is the pseudonym of the research institution described in this study used the mathematics Emporium to redesign its college algebra course.

Redesigned college algebra and traditionally-taught (hereafter traditional) college algebra sections were the two different research settings in this study. Throughout the dissertation “course redesign” refers to the mathematics Emporium unless otherwise mentioned. Under the scope of this study, course redesign is defined as delivering course content through the mathematics Emporium, which was enhanced by technology-supported teaching and learning activities, in a student-centered collaborative learning environment, and “traditional format” is defined as delivering course content through instructor-led teaching practices in a face-to-face lecturing environment.

Before the redesign, college algebra had been taught in the traditional format for many years at Urban U. The traditional college algebra course required three 50-minute face-to-face instructor-centered lectures each week (MSCRI, 2011, 2012). In the traditional format, major teaching and learning practices were instructor presentations; students were passive listeners. Many of the students took notes. They were allowed to ask questions, but this did not seem an effective practice that supported learning and interaction. Student-student and student-instructor interactions were limited in this traditional learning environment. Assessment in the course was structured on homework with ill-structured feedback, and midterm and final exams.

The mathematics Emporium model, on the other hand, eliminated all traditionally-taught instructor-centered lectures, and replaced those with an interactive learning lab which is a fully equipped computer lab that allows students to work in groups using interactive software and getting on-demand help and immediate feedback (NCAT, 2015e). The Emporium model required two 75-minute interactive lab sessions and one 50-minute class meeting every week. The goal of the in-class meeting was not to lecture nor to review homework, but to encourage student-student and student-faculty interaction, to prepare students for evaluation and to screen for student understanding. The teaching method used a student-centered learning approach framed in constructivist learning theory. All students were active learners who cooperated and collaborated, interacted with online learning materials, and engaged in group learning activities in the redesigned learning settings. The textbook and educational assessment procedures were digitalized, and provided online through an electronic classroom management system. Assessment in the course was built on automated evaluation with immediate constructive feedback. Faculty roles were also changed in redesigned college algebra settings. The instructor was not a presenter anymore; rather, she/he was the facilitator of learning progress. Graduate

teaching assistants also had an important role in providing on-demand help while students were working individually or as a group. This on-demand help opportunity allowed students to ask questions and to get responses immediately, promoted faculty-student interaction, and supported one-on-one learning practices.

Almost all of the institutions that participated in the college algebra redesign initiative reported better or equivalent student learning outcomes, higher retention rates, and reduced cost of instruction. The mathematics Emporium redesign model requires significant changes in the dynamics of traditionally-taught college algebra and moves it to a student-centered constructivist learning environment, but there is no empirical evidence that explains why all these changes result in increasing academic achievement and retention rates. Therefore, analyzing the impact of all of these changes on psychosocial factors of learning holds promise to help researchers better understand why the mathematics Emporium model is successful.

Academic achievement and student retention are related to various psychosocial factors that include but are not limited to personality, motivation, study skills, and emotional control (Robbins, Lauver, Le, Davis, Langley, & Carlstrom, 2004; Robbins, Allen, Casillas, Peterson, & Le, 2006). Under the scope of this dissertation three psychosocial factors, students' attitude towards mathematics, students' motivation to learn mathematics and students' satisfaction with the instructional design and practices are measured and examined.

Learners' attitude towards mathematics along with motivation to learn mathematics has been well-studied in the K-12 education context, but research is limited at the higher education level. Likewise, students' satisfaction from the learning experiences is well-researched in online learning environments at the higher education level, but has not been examined in face-to-face or redesigned college level introductory mathematics courses. Additionally, previously developed

instruments that aim to measure students' attitude towards mathematics, motivation to learn mathematics, and satisfaction from the instructional design and learning experiences include traditional stems that generally address the dynamics of the K-12 mathematics learning experiences. Thus, there is a need to develop a new reliable and valid instrument that measures those three attributes - students' attitude towards mathematics, motivation to learn mathematics, and satisfaction with the instructional design and learning experiences by considering the dynamics of the mathematics Emporium model and possible impact of instructional and learning technologies on psychosocial factors of learning.

In her brief synopsis about the role of researcher, Marilyn Simon (2011) stated that “in quantitative studies, the researcher's role is, theoretically non-existent.” (p.1). In this regard, the researcher did not have an active role in decision making, planning or implementing the course redesign project or the teaching and learning practices of the traditional college algebra sections at Urban U. The researcher helped design a likert scale for the Department of Mathematics and Statistics under the guidance of the primary investigator (PI) of the course redesign initiative at Urban U and administered the survey. Data were collected and stored by the PI of the college algebra course redesign project, and shared with the researcher as archived data.

This is a manuscript-based dissertation, also called a European style dissertation. It consists of an introduction, three manuscripts which are written separately, but are conceptually related, and a conclusion section. The first manuscript, titled *Course Redesign and Infusion of Educational Technology into College Algebra*, is a general overview and literature review of college algebra. That manuscript outlines the efforts of a Mathematics and Statistics Department at a Midwest Research University in four areas:

- What the problems of college algebra are

- What has been done to remediate these problems
- The role of instructional and learning technology integration efforts in college algebra for better student learning outcomes
- The course redesign, the mathematics Emporium.

The second manuscript, titled *Measurement of Psychosocial Factors of Learning in the Math Emporium: Scale Development and Assessment*, reports psychometric analyses of a scale that was developed to measure students' attitudes towards mathematics, motivation to learn mathematics, and satisfaction with the instructional design and learning experiences in the redesigned college algebra context. The manuscript includes a rationale for developing a new instrument, and presents psychometric properties of the instrument such as validity evidences, internal replicability and reliability results.

The third manuscript, titled *Impacts of the Math Emporium Delivery Model on Psychosocial Factors of Learning in College Algebra*, reports results of comparative analyses conducted to examine how students' attitude towards mathematics, motivation to learn mathematics, and satisfaction from the instructional design and learning experiences change in traditionally-taught college algebra, and redesigned college algebra sections throughout the semester. The manuscript also compares the previously described psychosocial factors in traditional and redesigned college algebra.

Summary of Manuscript 1

Course Redesign and Infusion of Educational Technology into College Algebra

The manuscript outlines the problems of college algebra, and focuses on technology-supported remediation efforts for better learning outcomes through an extensive literature review. The manuscript highlights high enrollment rates, low academic achievement, low

retention rates and instructional deficiencies as the main problems of college algebra that need immediate attention. It cites changing mathematical needs of learners and societies, changing student demographics and expectations, lack of students' mathematical preparation, ineffective teaching methods, and ill-structured instruction as reasons for these problems. It summarizes technology-supported remediation efforts in college algebra by emphasizing the use of calculators for better student learning outcomes; use of supplemental instruction and video-supplemental instruction to promote collaboration for increasing academic achievement and retention rates, use of computer assisted instruction and web-based learning practices for better student performance and enhanced instructional practices; and use of learning management systems for enhancing methods of content delivery to meet the diverse educational needs of learners. Finally, the manuscript outlines course redesign efforts at a Midwest research university by briefly introducing NCAT redesign models including the mathematics Emporium and the story of the institution that participated in the statewide course redesign initiative. The first manuscript addresses the need for a comprehensive review of literature and a summary of technology integration efforts to remediate the issues of traditionally-taught college algebra.

Summary of Manuscript 2

Measurement of Psychosocial Factors of Learning in the Math Emporium: Scale Development and Assessment

The overall goal of the manuscript is to examine the psychometric properties of the scale, Psychosocial Factors of Learning in Redesigned Introductory College Mathematics (PFL-RICM), which was designed to measure students' attitudes toward mathematics, motivation to learn mathematics, and satisfaction with the instructional design and learning experiences in redesigned college level mathematics courses. The manuscript starts with an extensive literature

review as a rationale for developing a new instrument to measure psychosocial factors of learning in the redesigned college algebra context by offering new stems that address the instructional dynamics of course redesign, the mathematics Emporium, such as getting immediate feedback, cooperative and collaborative learning activities, physical learning environment, assessment practices and procedures etc. It includes brief definitions of the concepts that the instrument is supposed to measure, and introduces previously developed instruments to measure psychosocial factors of learning in a K-12 context. The manuscript reports the results of a series of psychometric analyses as evidences of reliability and validity. It discusses content validity, face validity, response process validity, and internal structure validity evidences. As a result of initial exploratory factor analyses, the final form of the PFL-RICM scale consisted of 38 items which included one descriptive item, two random responding control items, and 35 likert items that were loaded under eight factors: Attitude towards mathematics, attitude towards technology-supported mathematics, beliefs about learning mathematics, extrinsic motivation, intrinsic motivation, satisfaction from mathematics instruction, satisfaction from course redesign efforts, and overall satisfaction from the mathematics learning experiences. The manuscript also includes results of internal replicability analyses, and reports Cronbach's alpha reliability coefficients which are at a desirable level. The second manuscript addresses the need for a new instrument that includes questions focusing on course redesign dynamics beyond the traditional stems that propose measuring learners' attitude towards mathematics, motivation to learn mathematics, and satisfaction from the instructional design and learning experiences.

Summary of Manuscript 3

Impacts of the Math Emporium Delivery Model on Psychosocial Factors of Learning in College Algebra

The ultimate goal of the manuscript is to examine changes in students' attitudes toward mathematics, motivation to learn mathematics, and satisfaction with the instructional design and learning experiences in traditionally-taught and redesigned college level mathematics courses. Investigated research questions were: (a) Do attitudes toward mathematics, motivation to learn mathematics, and satisfaction from the mathematics learning experiences change significantly during redesigned and traditional college algebra sessions? (b) Is there a statistically significant difference between the psychosocial factors of learning in both forms of college algebra after controlling for pre-existing scores? The following nine hypotheses were tested through paired samples t-tests, and multiple regression.

H₀A: There are no statistically significant changes in students' attitudes toward mathematics, attitudes toward technology-supported mathematics, beliefs about learning mathematics, and overall attitudes toward mathematics within traditionally-taught college algebra sessions over the course of a semester.

H₀B: There are no statistically significant changes in students' intrinsic motivation to learn mathematics, extrinsic motivation to learn mathematics and overall motivation to learn mathematics within traditionally-taught college algebra sessions over the course of a semester.

H₀C: There are no statistically significant changes in students' satisfaction from mathematics instruction, satisfaction from technology-supported mathematics education, satisfaction from instructional design, and overall learner satisfaction from the college algebra within traditionally-taught college algebra sessions over the course of a semester.

H₀D: There are no statistically significant changes in students' attitudes toward mathematics, attitudes toward technology-supported mathematics, beliefs about learning mathematics, and overall attitudes toward mathematics within redesigned college algebra sessions using the Emporium model over the course of a semester.

H₀E: There are no statistically significant changes in students' intrinsic motivation to learn mathematics, extrinsic motivation to learn mathematics and overall motivation to learn mathematics within redesigned college algebra sessions using the Emporium model over the course of a semester.

H₀F: There are no statistically significant changes in students' satisfaction from mathematics instruction, satisfaction from technology-supported mathematics education, satisfaction from instructional design, and overall learner satisfaction from the college algebra within redesigned college algebra sessions using the Emporium model over the course of a semester.

H₀G: There is no statistically significant difference between traditionally-taught and redesigned college algebra sessions regarding students' attitudes toward mathematics, attitudes towards technology-supported mathematics, beliefs about learning mathematics, and overall attitudes towards mathematics after controlling for pre-determined attitude, motivation, and satisfaction scores.

H₀H: There is no statistically significant difference between traditionally-taught and redesigned college algebra sessions regarding students' intrinsic motivation to learn mathematics, extrinsic motivation to learn mathematics, and overall motivation to learn mathematics after controlling for pre-determined attitude, motivation, and satisfaction scores.

H₀I: There is no statistically significant difference between traditionally-taught and redesigned college algebra sessions regarding students' satisfaction from mathematics instruction, satisfaction from technology-supported mathematics education, satisfaction from instructional design, and overall learner satisfaction from the college algebra after controlling for pre-determined attitude, motivation, and satisfaction scores.

Although the course redesign approach for remediating college-level introductory courses was introduced nearly two decades ago, course redesign remains a new concept in college algebra, and empirical research is limited to reports prepared for NCAT by participating institutions. These reports heavily focus on academic achievement measured by final exam grades, retention rates measured by withdrawal rates, and cost effectiveness measured by the instructional cost per student of the models. However, changes in the psychosocial factors of learning have not been empirically examined although some institutions anecdotally reported changes in students' attitudes towards subject matter, faculty and student satisfaction, and motivation to learn. Thus, the final manuscript addresses the need for an empirical research study that focuses on the psychosocial factors of learning in the two delivery methods for college algebra courses.

Summary

This manuscript-based dissertation is a comprehensive analysis of psychosocial factors of learning in a redesigned college algebra context in which learning technologies are heavily used. Three conceptually-related manuscripts were developed, and all manuscripts support the entire framework of this dissertation. Each manuscript fills a specific gap in college level mathematics education literature. The first manuscript addresses a need for a comprehensive literature review

that focuses on college algebra remediation efforts, summarizes technology integration practices and outcomes, and introduces the mathematics Emporium, an emerging trend in the college algebra course redesign. As a result, the manuscript outlines the common problems of college algebra, technology-supported remediation efforts; and the mathematics Emporium, which is the context in which data were collected and research was conducted. The second manuscript addresses the need for a new, valid and reliable instrument that measures students' attitude towards mathematics, motivation to learn mathematics, and satisfaction from the instructional design and practices in redesigned college algebra settings. The manuscript defines attitude towards mathematics, motivation to learn mathematics, and satisfaction from the instructional design and practices, and reports psychometric analyses of the scale developed specifically by considering the dynamics of the mathematics Emporium delivery model. The final manuscript examines data collected via the survey developed in the second manuscript and investigates whether students' attitude towards mathematics, motivation to learn mathematics, and satisfaction from the instructional design changes significantly during a semester, and whether these variables differ significantly in redesigned and traditionally-taught college algebra sections after controlling for pre-determined scores. The final chapter of the dissertation summarizes the findings of psychometric analyses in the second manuscript, and empirical findings of the third manuscript by revisiting methods and procedures of statistical analyses.

CHAPTER 2

COURSE REDESIGN AND INFUSION OF EDUCATIONAL TECHNOLOGY INTO COLLEGE ALGEBRA

Abstract

College algebra is one of the courses renowned for high enrollment rates, low academic achievement, and low retention rates. For many years, integration of instructional and learning technologies (ILT) has been considered as a remediation in college algebra to address these problems and to minimize undesired learning outcomes for many years. Infusion of the ILT into college level mathematics instruction has gained more attention with course redesign efforts supported and guided by the National Center for Academic Transformation (NCAT) for more than a decade. This chapter discusses the recent efforts for integrating the best practices of instructional and learning technologies with the best practices of pedagogy for better learning outcomes and optimized retention rates in the college algebra context.

Introduction

College algebra is renowned for undesirable pedagogical outcomes such as high dropout rates, low academic achievement and low retention rates. Such undesirable educational outcomes cause college algebra to become a target course needing immediate attention to increase the quality of students' learning experiences and academic achievement. Unfortunately, the purpose and content of the course, the way it is taught, and its problems have been consistent for many years (Ganter & Haver, 2011; Gordon, 2008, 2013; Lazari, 2007; Mayes, 2004; Small, 2002). Integration of instructional and learning technologies (ILT) such as calculators, video-supported instruction, computer-assisted instruction and web-based instruction has been considered as an option having potential to change the way college algebra is taught and to address some of the persistent problems of college algebra. However, the use of ILT in college algebra sections has been limited by individual efforts, and has received little attention at the institutional level for many years despite the fact that use of ILT in education has increased dramatically since the 1990s at all grade levels. For more than a decade, college algebra has attracted more attention at the institutional level, and the way college algebra is taught has been changing recently in order to meet the diverse educational needs of learners and society (Ganter & Haver) with the help of systematic integration of ILT. In order to increase student learning outcomes, low-performing elements of instruction are being changed as they are altered in industry (Garza, Havlak, Riggs, & White, 2000) by using ILT in college algebra courses. Indeed, it is a necessity because the majority of the college algebra courses have been taught using traditional teaching practices which focus on teacher-centered and lecture-based instruction and generally fall behind satisfying the educational needs of 21st century learners. Small notes that “[t]raditional College

Algebra is not working. That was the strong consensus of the participants in a recent Conference to Improve College Algebra, held at the U. S. Military Academy, February 7-10, 2002” (p. 1).

The Conference Board of Mathematical Sciences (CBMS) collects data on undergraduate programs in the mathematical sciences in the United States every five years by collaborating with the National Science Foundation (NSF) (Blair, Kirkman, & Maxwell, 2013). Blair, Kirkman and Maxwell published the fall 2010 CBMS survey results in 2013. The survey revealed that 65% of the mathematics departments at four-year colleges and universities taught college algebra by primarily using a traditional approach. The traditional mode of instruction might not satisfy the learning needs of 21st century learners who are active learners and users of technology in education. For example, the principles of social constructivism are not well-considered in traditionally taught college algebra courses although Piaget (1976) states “social interaction is a necessary condition for the development of logic” (p. 80), and Schoenfeld (1992) defines mathematics as an “inherently social activity” (p. 335). ILT and redesigned college algebra sections support student-centered mathematics learning environments in which learners are socially active. Students can collaborate, communicate, and interact to develop mathematical competency and skills to be well-prepared for the advanced academic courses and real-life problems in technology-supported interactive learning settings. This chapter defines instructional and learning technologies from a broad perspective as digital and web-based instructional tools and practices used to improve the quality of learning outcomes. It specifically focuses on incorporation of ILT in college algebra courses. The chapter outlines the recent literature by emphasizing current problems of college algebra, the role of ILT in remediating college algebra, and technology-supported course redesign efforts of a Mathematics and Statistics Department at a public research university located in the Midwest.

Definition and Purpose of College Algebra

Students who are not ready to take advanced mathematics courses such as calculus and numerical analysis, and other discipline-specific mathematics courses such as business mathematics and mathematics for liberal arts are required to enroll in college algebra or developmental mathematics courses. College algebra along with developmental mathematics courses are considered gatekeeper courses which help institutions control enrollment of students who are not qualified for further academic studies (Armington, 2002). Originally, the goal of designing college algebra and pre-calculus courses was to prepare weaker students to succeed in mainstream calculus by developing their algebraic skills. This is still the goal in many institutions today (Gordon, 2008). College algebra can also be used to prepare students to solve real-life problems besides preparing them for calculus (Fox & West, 2001; Herriott & Dunbar, 2009). Ganter and Haver (2011) define college algebra as a course which “provides students a college level academic experience that emphasizes the use of algebra and functions in problem solving and modeling, provides a foundation in quantitative literacy, supplies the algebra and other mathematics needed in partner disciplines, and helps meet quantitative needs in, and outside of, academia” (p. 45). The definition itself leads toward the well-determined goals of college algebra: to provide meaningful mathematical experiences and opportunities; to develop logical reasoning skills along with problem solving and mathematical modeling skills; to improve students’ ability to use technology and to communicate mathematical ideas and understanding; to develop competence and confidence to solve problems; and to strengthen students’ algebraic competencies useful in the other disciplines (Ganter & Haver). On the other hand, debates on content updates in college algebra have been persistent for many years because as Ganter and Haver state “[n]ationally, there is no general agreement on the content of college

algebra. Some institutions teach college algebra as a terminal mathematics course while other institutions view college algebra as part of the pre-calculus track” (p.51).

Problems of College Algebra

High enrollment rates, failing grades (D, F), and withdrawal (W) rates are the persistent problems which cannot be ignored in college algebra courses. Gordon (2008) listed additional problems of college algebra including changing student demographics, improvement in technology and its effects on mathematics instruction, and changing mathematical needs of learners.

High Enrollment Rates

Thousands of students enroll in remedial mathematics courses at four-year and two-year colleges and universities each year. This enrollment rate is problematic because of increased class sizes, decreased faculty-student ratio and the inflated cost of instruction. The CBMS survey results provide a detailed analysis of student enrollments in undergraduate level mathematics courses including college algebra. In fall 2005, the CBMS survey, which was used in mathematics and statistics departments at four-year colleges and universities, and in mathematics programs at two-year colleges, indicated that more than one million students enrolled in introductory mathematics courses including intermediate algebra, college algebra and pre-calculus (Gordon, 2013). The CBMS survey, administered in fall 2010, indicated that in five years, the number of students enrolled in introductory mathematics courses increased 20% and reached approximately 1.2 million. Such a dramatic increase in introductory mathematics course enrollments is not surprising, indeed expected, because each year an increasing number of high-school graduates are accepted into higher education programs. Current enrollment rates and estimated increased rates in the future indicate that a growing number of students will continue

to enroll in college algebra sections annually. Remediating college algebra courses could even become more challenging in the future. When large sections are specifically considered, traditional teaching methods might not be appropriate to reach such a large number of students whose educational needs vary widely despite the fact that those methods are routinely used everywhere. Therefore new teaching methods should be incorporated in teaching college algebra, and technology-supported instruction should be considered as an effective alternative to traditional teaching practices.

Low Academic Achievement, Failing Grades (D, F), and Withdrawal (W) Rates

Developmental mathematics courses including college algebra are well-known to have the highest DFW rates among other college level courses (Zelkowski & Goodykoontz, 2013). Although the range for DFW rates in college algebra appears to be 50-75% nationwide and can be up to 90% at some institutions, it is generally accepted that annually about 50% of the students enrolled in college algebra in the United States fail to receive a passing grade or drop the course (Benford & Gess-Newsome, 2006; Brewer & Becker, 2010; Gordon, 2008; Haver et al., 2007; Herriott, 2006; Mayes, 2004).

Gordon (2013) relates unacceptable poor achievement in college algebra courses to offering courses which do not satisfy the needs of the learners. Likewise, Mayes (2004) believes that the traditional focus on skill development triggers DFW rates in college algebra. Regardless of the reason, it is a fact that college algebra courses suffer from low academic achievement, high failure rates (D, F) and high withdrawal (W) rates. Small (2002) stated that “the high FDW rate — percentage of students receiving grades of F or D or withdrawing — is a major reason for the claim that traditional College Algebra is not working” (p. 1).

Instructional Deficiencies

Nationwide attention has been paid to poor academic achievement and low student retention in developmental mathematics courses, and course redesign and intervention strategies are often used to remediate such ill-structured courses including college algebra (Frame, 2012). As of today, the majority of the college algebra sections are taught using a traditional approach although there is consensus that “the traditional approach is not working” (González-Muñiz, Klingler, Moosai, & Raviv, 2012, p. 204). Institutions that offer college algebra have tried various options to improve the ways in which college algebra content is delivered hoping for improved student success and retention rates. As grouped by Epper and Baker (2009), these efforts include but are not limited to intensity models, reduction, redesign of curricula, project-based learning, contextual learning, acceleration, learning communities, and technology-supported instruction. Many of these efforts have yielded positive, but not satisfactory learning outcomes, because the focus of the instructional approach, the traditional mode of instruction, remained the same in many cases. Perhaps that is the reason why a need for change in instructional approach is at the top of the list of what needs to be done to improve instruction in college algebra.

Infusion of Technology in Mathematics and College Algebra

ILT have been implemented in mathematics teaching to enhance instructional practices and to increase student success for many years. Gifford (1996) classified technology integration in education as either a mediated learning model in which technology supports the learning process as a whole, or a “bolt-on” model which integrated technology to support instructors, content, and students separately. The latter model of technology integration has been employed for many years. However, course redesign efforts have changed the way of integrating

technology into college level mathematics classrooms, and this new trend is built on a mediated learning model which puts the student at the center of the learning process.

Technology such as the abacus, ruler, protractor, compass etc. has been used in teaching and learning mathematics throughout the history of mathematics, but more attention has been paid since technology was digitalized. Today, the definition and use of ILT in mathematics education are not well-defined, and technology may refer to calculators, classroom management systems and student response systems, distance and online teaching practices, simulations, visualizations and video-supported instruction, and computer-assisted instruction in mathematics education (AMATYC, 2004). Students have become more and more dependent on the use of technology in mathematics education because technology integration has been considered a dominant factor which has potential to remediate college level mathematics (Gordon, 2008; Hagerty & Smith, 2005). Epper and Baker (2009) claimed that there is a consensus that developmental mathematics courses might fail to achieve intended student learning outcomes unless technology is incorporated. Kinney and Robertson (2003) stated that “the goal of incorporating technology into developmental mathematics programs is not to develop a single instructional model that best meets the needs of all students but rather, to offer students more choices in terms of ‘where, when and how’ they learn mathematics” (p. 316). Prensky (2001) noted that debating the use of technology in mathematics is pointless because technology is part of students’ daily lives, and mathematics educators should discuss how to use technology effectively to support the learning and conceptual understanding of mathematics.

It should be emphasized that integration of technology in mathematics education raises its own positive and negative considerations, and might affect student learning outcomes negatively unless it is used along with best pedagogical practices in mathematics classrooms to address the

diverse mathematical needs of learners. It is a fact that the development of conceptual understanding in mathematics cannot be achieved solely by technology integration (Taylor & Mittag, 2001), so blending technology with the best instructional practices for better learning outcomes is a necessity in college level mathematics courses. For many years, calculators, computer-assisted instruction (CAI), video-supported instruction (VSI), web-based teaching and technology-supported course redesign efforts supported by the National Center for Academic Transformation (NCAT) have been the major efforts of technology integration in mathematics classrooms including college algebra.

Calculators

The movement of digitalized technology integration in mathematics education started many years ago with the incorporation of calculators in mathematics classrooms. Calculators were the predominant educational technology in the 1980s before computers and hand-held devices (e.g., tablets and cell phones) became widely available in classrooms, or accessible by students for personal use. With the developments in technology, calculators have evolved through the years, and have become more complicated electronic devices which are capable of not only calculating, but also graphing. Horton, Storm, and Leonard (2004) stated that “graphing calculators have been used in the mathematics classroom for speed, to leap hurdles, to make connections among representations, and to permit realism through the use of authentic data” (p.152). As a result, research indicates that the use of (graphing) calculators in mathematics classrooms positively affects the learning experiences of students (Horton, Storm, & Leonard; Ruthven, 1990; Smith & Shotsberger, 1997; Tolia, 1993).

Thousands of students have used calculators in mathematics although the debate on their effectiveness persists. Since calculators externalize information processing, it should be

determined whether they enhance the conceptual understanding of mathematics, or minimize mathematical thinking. Barton (2000) summarized that

Thirty-two studies investigated conceptual understanding and/or spatial visualization of mathematical concepts. Eighty-eight different results were provided concerning conceptual understanding (including problem solving and visual thinking). There were 66 statistically significant results favoring the experimental/treatment group while one study reported two results on conceptual understanding that favored the control group. Twenty results indicated no significant difference between the experimental group and the comparison group on conceptual understanding. (p. 4)

In a meta-analysis, Hembree and Dessart (1986) studied the effects of calculators in mathematics, and concluded that nearly 50% of the studies examined reported significant increase in achievement of students, whereas the remaining 50% did not. While discussing the role of calculators on academic achievement and conceptual understanding of mathematics based on research findings, the way calculators are incorporated in mathematics education and whether they are allowed to be used on exams should be considered. Gordon (2013) stated that graphic calculators are introduced to students as early as the 8th grade, and it might not be logical to suggest that these students perform better on standardized tests or regular exams if they are not allowed to use graphing calculators. Likewise, Schwartz (2007) compared that

On the one hand, graphics calculators and computer software now exist that enable teachers to show sophisticated graphs and three-dimensional models that students can actually see rather than try to imagine. In addition, technology has made mathematics more precise [...] on the other hand, technology has meant that many students rely on calculators or spreadsheet programs for computation, which means they might not be proficient in basic arithmetic operations. This could result in a failure to have a sense of numbers and a diminished ability to determine the reasonableness of a solution or calculation. (p. 40)

Barton (2000) cited from Suydam (1976; 1980) that there is no adverse effect from using calculators in mathematics; rather they possibly increase student achievement when they are used appropriately.

Research on graphing calculators in college algebra classrooms is limited although the use of calculators such as graphic calculators, scientific calculators and calculators with algebra systems is common at four-year colleges and universities and two-year colleges. Blair, Kirkman and Maxwell (2013) noted that nationwide 66% of the 4-year colleges and universities and 65% of the two-year colleges allow learners to use graphing calculators in college algebra classrooms in the fall 2010 semester. In a meta-analysis that focused on computer-enhanced instruction (CEI) on college level mathematics, King (1997) concluded that graphing calculators have statistically significant positive effects on academic achievement, and a significant effect on procedural achievement is noted when students are allowed to use calculators in exams. The procedural understanding of students was negatively affected if students were not allowed to use graphing calculators in exams, and likewise conceptual achievement of students was affected negatively when graphing calculators were accessible in the classroom or in the lab although the evidence was not statistically significant (King).

Supplemental Instruction

The Supplemental Instruction (SI) model was developed by Dr. Deanna Martin in 1973 at the University of Missouri-Kansas City (UMKC), and the SI approach gained national and international attention in a short time. Pemberton (2011) defined supplemental instruction as an approach that “utilizes a non-remedial, collaborative approach to learning that increases student performance and retention by offering peer-led, regularly scheduled, out-of-class review sessions” (p. 1). Martin and Arendale (1992) emphasized that SI develops a sense of community, facilitates student involvement and academic and social integration, and enhances affective and cognitive development. Improving student learning outcomes, increasing retention and graduation rates in historically difficult courses are the major goals of the SI approach (UMKC,

2014). The Supplemental Instruction Fall 2002-Spring 2013 National Data Report (UMKC) indicated that supplementary instruction targets the courses that fall behind achieving their desired educational goals, rather than learners, through well-trained SI leaders, collaborative learning activities and voluntary participation (UMKC).

Data collected from 69 Institutions (5,686 courses and 726,320 students) indicate a notable difference between the DFW rates (respectively 17% vs 31%) in SI supported courses and non-SI courses; and between the means of final grades (respectively 2.56 vs 2.19) in SI supported courses and in non-SI courses at all institutions (UMKC, 2014). Supplemental instruction has been used to minimize undesired learning outcomes in college algebra as one of the historically difficult courses, as well. According to the SI report (UMKC, 2014a) institutions that utilize SI in mathematics departments reported 22% DFW rates and 2.35 mean final grade, whereas non-SI institutions reported 31% DFW rates, and 2.09 mean final grade nationwide (UMKC, 2014a). Lazari and Simmons (2003) compared the final exam scores of students enrolled in SI and traditional college algebra sections. As a result, they reported that differences between the means of final exam scores between the groups are not statistically significant in three consecutive semesters although the SI group performed slightly better than the traditional group in the fall 2001 and in the spring 2002 semesters.

As an alternative form of supplemental instruction, video-based supplemental instruction (VSI) requires students to enroll in video sections of the course rather than in traditional sections, and utilizes video-taped traditional lectures for self-paced learning under the supervision of an SI facilitator in a collaborative learning environment (UMKC, 2014b). Martin and Blanc (2001) stated that VSI participants outperformed their peers who were taught by the same instructor in the same, large, traditional course in terms of significantly increased passing grades and mean

final course grades, and decreased failure and withdrawal rates. Hurley, Patterson and Wilcox (2006) reported comparison of ACT scores and college algebra grades of students who enrolled in VSI and Non-VSI sections between 1999 and 2004. The average ACT mathematics score of students who enrolled in VSI sections (17.20, N=316) was lower than the scores of students who enrolled in non-VSI sections (20.55, N=2450), but students who enrolled in VSI sessions outperformed their peers enrolled in Non-VSI sessions of their college course (Hurley, Patterson & Wilcox).

Unlike VSI courses, Wynegar and Fenster (2009) reported better student achievement in traditional college algebra sections than in sections using television. Although SI and VSI yielded positive changes in academic achievement and student retention in general, it seems that neither of them provided significant contributions to college algebra. Perhaps, this is because the majority of the students enrolled in SI and VSI sections were mathematically unprepared which is confirmed by the high school GPAs and SAT-Math scores that were statistically significant in both groups in college algebra sections (Lazari & Simmons, 2003).

Computer-Assisted Instruction and Web-based Learning in College Algebra

Computer-Assisted Instruction (CAI), in general, is the term that is used interchangeably with computer-based instruction, computer-supported instruction and computer-aided instruction. In the field of mathematics, traditional classroom instruction has been supported by CAI for many years (Epper & Baker, 2009). CAI was implemented in college algebra sections hoping to enhance the way content is delivered and hoping to increase student achievement. CAI research yields promising learning outcomes in college algebra. In a comparative study, O'Callaghan (1998) analyzed the effects of CAI on student performance in college algebra classrooms and concluded that students enrolled in CAI sections performed better than students

enrolled in traditional sections in terms of understanding functions, exhibiting positive attitude changes and showing reduced mathematics anxiety. Likewise, Stephens and Konvalina (1999) reported better student achievement in CAI supported college algebra sections in addition to positive student feedback and better teacher evaluations although the difference between groups was not statistically significant. On the other hand, Wynegar and Fenster (2009) compared several instructional approaches such as traditional classroom teaching, computer-assisted instruction, online instruction and television in college algebra classrooms and reported that students enrolled in traditional college algebra sections performed significantly better than students in other sections.

As a form of computer-assisted instruction, a web-based or online teaching approach has been used with college algebra sections for better learning outcomes and increased retention rates. Use of online courses and learning modules, and incorporation of the internet to support instructional methods have increased dramatically in the last decade in science, technology, engineering and mathematics (STEM) disciplines (Fowler & Hasebrook, 2001; Hauk & Segalla, 2005; NSF, 1998). Aichele, Francisco, Utley, and Wescoatt (2011) noted that “[a]ugmented by online resources and instant feedback, the course could become a more active experience for students, with most of their time spent doing mathematics rather than passively watching mathematics” (p. 2).

The research on web-based college algebra is limited in the literature. McSweeney and Weiss (2003) reported that students enrolled in Math Online, which is a web-based system developed by the Fairfield University Mathematics and Economics Departments to move the mathematics instruction out of the classroom context, had higher mean scores than students enrolled in non-Math Online sections. Taylor (2008) also reported that students enrolled in web-

based intermediate algebra courses showed better learning outcomes. Stillson and Alsup (2003) concluded that students who engaged with online mathematics teaching and learning tools such as ALEKS, which is a web-based learning system, develop a better understanding of mathematical concepts. Brewer and Becker (2010) examined the effectiveness of online homework on the achievement of unprepared and repeating college algebra students, and reported that students enrolled in online homework programs performed better on the final exam than the students who took a traditional textbook-based/homework class although the difference between the groups was not statistically significant. Likewise, Hauk and Segalla (2005) found no significant difference between achievement of students who complete web-based homework and paper-based homework although web-based homework reduced the time spent on grading.

Learning Management Systems and College Algebra Redesign

Vaughan (2010) stated that “[t]he role of technology shifts from the packaging and distribution of content to being used as a “tool set” to enable students to communicate and collaboratively construct their own knowledge” (p.61). Learning Management Systems are “tool sets” consisting of various advanced ILT. Like computer-assisted instruction, the term “learning systems” is used interchangeably with course management systems (CMS), virtual learning environments (VLE), learning management systems (LMS), and learning content management systems (LCMS) (Roqueta, 2008). Learning systems offer alternative ways for the delivery of course content, management of the learning process and assessment procedures by combining various ILT in one platform. Course management systems which focus on the delivery of course content in general were first introduced in the 1990s, and have evolved to learning management systems which focus on learners and learning outcomes (Roqueta, 2008 cited from Simonson, Smaldino, Albright, & Zvacek, 2006). LMS provides institutions flexibility to deliver the course

content in different formats such as online or in a blended mode of instruction by considering the educational needs of the learners. Instructors can transform their teaching practices to meet the diverse needs of the learners by using the LMS (Morgan, 2003). Although empirical research and statistical outcomes of the LMS in the college algebra context is limited, different learning solutions offered by commercial enterprises are promising to make learning more effective, to create collaborative and comprehensive learning environments, and to optimize retention rates (Blackboard, 2014).

One of the advantages of the LMSs is to allow learners to access the course content through various audio-visual materials such as interactive tutorials, and assessment tools in addition to facilitate communication and collaboration outside of the classroom. Kersaint, Dogbey, Barber, and Kephart (2011) examined the effects of students' access to online tutorials on students' academic achievement in college algebra, and concluded that students who had access to the online tutorials indicated higher content knowledge gains than students who did not have access to the online tutorials. Lazari and Simons (2001) compared academic achievement and retention rates in fully online and traditional sections of college algebra, and concluded that "there is not enough statistical evidence to conclude that one method is better than the other, either for the retention rate or academic achievement as measured by the final examination" (p.171).

The impact of the CMS/LMS on college algebra classrooms has gained more attention with the implementation of course-redesign efforts in college algebra classrooms. Twigg (2011) defined course redesign as a process of redesigning courses as a whole for better learning outcomes and reduced cost rather than targeting specific sections by implementing the best practices of ILT. Most of the redesign efforts require extensive use of CMS/LMS which designs

an online learning environment for alternative course delivery (Twigg, 2003b). Aichele et al. (2011) stated that course redesign models which are supported by LMS provide learners flexibility to complete course requirements including the assignments with immediate feedback online to master the content. All course redesign models consider high level integration of ILT in college algebra sections, and propose to address the major problems such as low academic achievement, low retention rates and cost of instruction in college algebra courses (Aichele et al.). According to Johnson, McAlpin and An (2012), nationwide, the number of higher education institutions that implement large course redesign models for better learning outcomes has increased dramatically. They further summarized the nationwide affirmative outcomes of the large course redesign efforts as “improved grade distribution, increased retention of discipline-specific knowledge, enhanced engagement and interaction, improved student and faculty satisfaction, increased enrollment, increased flexibility in course design, and reduced cost” (p. 2). Twigg (2011) stated that course redesign is not the process of delivering the courses online, but to develop alternative ways to deliver the course content through ILT.

In conclusion, major problems associated with college algebra such as high enrollment rates, low retention rates and low academic achievement are similar and persistent at higher education institutions across the country. Integration of ILT has been used as a remediation for undesired learning outcomes in college-level mathematics instruction for many years. According to Bargagliotti, Botelho, Gleason, Haddock, and Windsor (2012), it is common sense that technology positively affects student learning of mathematics by promoting student-centered and constructivist learning settings. As Epper and Baker (2009) stated “[m]any experts in the world of mathematics and beyond contend that we cannot meet our developmental math student success goals without incorporating technology” (p. 3). Integration of technology in mathematics

education accelerated after educational technology became digitalized. Calculators were the predominant educational technology in the 1980s in mathematics education, and they were replaced by the internet and personal computers in the 1990s. Discussions about the role of technology in education gained more attention after the internet and computers became easily accessible at schools and at higher education institutions. Advancements in ILT have influenced mathematics education at all grade levels because of the efforts of mathematics communities such that National Council of Teacher of Mathematics (NCTM), the American Mathematical Society (AMS), the Mathematical Association of America (MAA), and the American Mathematical Association of Two-Year Colleges (AMATYC). LMS combine several advanced ILT in one platform and for more than a decade have helped educators to design better learning experiences for learners not only by enhancing the traditional mode of instruction, but also by designing virtual learning environments. Harkness, Lane and Hardwood (2003) concluded that cost-effective course redesign creates a student-centered, collaborative and technology-enhanced learning environment in which LMS are used for effective content delivery and assessment. Course redesign efforts supported by integration of LMS are promising to address the general problems of college algebra courses. The following sections of the paper discuss the course redesign efforts in college algebra classrooms. An increasing number of higher education institutions which are looking for solutions to address major college algebra problems such as high enrollment, attrition rates and low student achievement are using NCAT supported course redesign models, and the next section outlines the course redesign efforts in general.

Course Redesign

National Center for Academic Transformation (NCAT)

The National Center for Academic Transformation (NCAT) is a leading non-profit organization that is committed to helping institutions redesign large enrollment courses by using ILT to achieve desired student learning outcomes and reduce the cost of instruction (NCAT, 2015g). NCAT was funded by the PEW Charitable Trusts in 1999 to establish the initiative (NCAT), and has financially supported or guided several higher education institutions in their redesign of large-enrollment courses to optimize student learning outcomes. The Program in Course Redesign (PCR) of the NCAT was funded by PEW Charitable Trusts between 1999 and 2003. The second and third phases of the course redesign efforts (respectively Roadmap to Redesign (R2R) between 2003 and 2006 and Colleagues Committed to Redesign (C²R) between 2006 and 2009) were funded by the Fund for the Improvement of Postsecondary Education (FIPSE). The final phase, Changing the Equation, was funded by the Gates Foundation between 2009 and 2012 (NCAT). Thirty courses including linear algebra, intermediate algebra and college algebra were redesigned during the PCR period; twenty institutions were supported in R2R program, and twelve of them completed the redesign projects. Among those twelve institutions, four of them redesigned college algebra sections which suffered from high enrollment rates, high attrition rates and low student learning outcomes; twenty-nine courses were redesigned during the C²R program and, ten of them focused on pre-calculus level courses including five redesign projects which specifically focused on college algebra. Finally Changing the Equation focused solely on redesigning developmental mathematics courses at 38 participating institutions (NCAT).

There is no fixed model for course redesign that fits perfectly for each discipline or course, but NCAT offers six different course redesign models, from which participating institutions can choose: supplemental, replacement, fully online, buffet, linked workshop, and emporium (NCAT, 2015e). Each redesign model has its unique requirements, and participating institutions have flexibility to choose one of the redesign models based on the educational needs of their students and on the financial and instructional goals of their institutions. Each model distinguishes itself from the others in terms of in-class and out of class activities. For example, “[o]ne version of the replacement model replaces some class meetings with online activities while keeping in-class activities more or less the same. Others replace some class meetings with online activities and also make significant changes in what goes on in the remaining class meetings” (Twigg, 2003b, p.33). Course redesign not only changes the role of instructors, but also changes the role of students who become active participants in the learning process rather than being passive listeners (Harkness, Lane, & Harwood, 2003; Thiel, Peterman, & Brown , 2008; Villarreal, 2003; Ye & Herron, 2010).

NCAT Redesign Models

- *Supplemental Model:* The traditional mode of teaching is supported with the implementation of ILT. The supplemental model purposes to improve student involvement through off-campus learning activities which might or might not affect in class practices (NCAT, 2015e). The University of New Mexico, Carnegie Mellon University, The University of Massachusetts-Amherst and The University of Colorado at Boulder are some of the institutions that implemented the supplemental model of course redesign (NCAT, 2015g).

- *Replacement Model:* The focus of the replacement model is to reduce the number of face-to-face meetings, and to replace eliminated in-class meetings with online interactive educational practices and tasks while enhancing the retained in-class activities (NCAT, 2015e; Twigg, 2003b). Penn State University, The University of Wisconsin-Madison, The University of Tennessee-Knoxville, Portland State University and Tallahassee Community College are some of the institutions that used the replacement model in their course redesign projects (NCAT, 2015g).
- *Fully online Model:* The fully online model combines the characteristics of the supplemental, replacement and emporium models, and designs online learning experiences by eliminating all in-class meetings (NCAT, 2015e). Twigg (2003b) summarized that “[t]his model assumes that the instructor must be responsible for all interactions, personally answering every inquiry, comment, or discussion. As a result, faculty members often spend more time teaching online and interacting with students than is the case in classroom teaching” (p. 35). The model strongly depends on the LMS and active integration of ILT into educational practices. Rio Salado College, The University of Southern Mississippi, and Florida Gulf Coast University implemented this model in redesigning high enrollment courses (NCAT, 2015g).
- *Buffet Model:* The buffet model organizes the learning environment based on individual learning needs and study skills of learners by providing different learning experiences and opportunities, various assessment options, and module by module course structure (NCAT, 2015e; Twigg, 2003b). Learning opportunities provided by the buffet model can be adopted based on the preferences of learners (Twigg). The Ohio State University

redesigned an introductory statistical concepts course by adapting the buffet model of NCAT (NCAT, 2015g).

- *Linked workshop model:* In general, the linked workshop model focuses on remedial and developmental college level courses and proposes to design a supportive learning environment by linking the traditional course structure with workshops which “consist of computer-based instruction, small-group activities and test reviews to provide additional instruction on key concepts” (NCAT, 2015g, p.1).
- *Emporium Model:* The emporium model moves the traditional classroom-based lecture to interactive learning labs which provide on-demand personalized assistance and online delivery of course content (NCAT, 2015e). According to Twigg (2011), the emporium model yields better learning outcomes and cost reduction rates when compared to the others. ILT such as modularized online interactive tutorials, online assessment with immediate feedback and online course materials, and interactive navigation which provides students immediate explanations and examples are the core elements of the emporium model (Twigg, 2003b). Like the supplemental and replacement models, the implementation of the emporium model also varies among institutions and courses are redesigned based on needs of the institutions and learners (Twigg, 2003b). Twigg (2011) stated that the emporium model gained more attention for course redesign in mathematics because project evaluations indicated increased academic achievement and reduced instructional costs in developmental and college level mathematics courses. According to Twigg (2011), spending time on doing mathematics rather than listening to a lecture, self-paced learning opportunities, on-demand assistance and requiring students to do

mathematics are the four main reasons why the emporium model is successful in mathematics course-redesign.

The emporium model gained nationwide attention in redesigning college level mathematics courses because of its potential to help institutions optimize student learning outcomes while reducing instructional cost. Nationwide, 195 redesign projects have been implemented in total, and 80% of the projects which affect approximately 250,000 students annually were completed (NCAT, 2015g). In the first phase, Program in Course Redesign, Northern Arizona University redesigned college algebra by adapting the emporium model, and reported no statistically significant difference between the final exam scores and retention rates of redesigned and traditional college algebra sections although students enrolled in the redesigned sections performed slightly better (NCAT, 2015f). In the R2R phase, Louisiana State University and the University of Missouri-St. Louis followed the emporium model to redesign college algebra. Louisiana State University reported lower academic achievement in redesigned sections by noting that students enrolled in redesigned sections had impressive scores when the computer-mediated assessment did not give them partial credit. The University of Missouri-St. Louis reported statistically significant positive learning outcomes and retention rates in redesigned sections when compared to student achievement in traditional sections of college algebra. A majority of the institutions that participated in the final phase, Changing the Equation, used the emporium model in remedial and developmental college level mathematics courses, and 86 courses were redesigned; seventy-one percent of the courses showed statistically significant improvements, whereas six percent of the courses indicated positive learning outcomes which were not statistically significant (NCAT, 2015g).

NCAT also developed partnerships with state and national higher education communities to expand the course redesign efforts through a three-phase process: (a) developing awareness and commitment, (b) campus planning and implementation, and (c) capacity building and scaling (NCAT, 2015g). By following the same approach, NCAT developed a partnership with the Missouri Four-Year Public Institutions (MFYPI) to redesign large enrollment courses (NCAT). MFYPI proposed developing a course redesign program based on the lessons learned from nationwide NCAT course redesign models; to find new ways to enhance students' learning experiences and improve academic achievement; to reduce the cost of instruction; to develop model course redesigns that are applicable to other statewide institutions; and to educate the faculty and staff for further implementation of course redesign projects (NCAT) by partnering with the NCAT. The Missouri Statewide Course Redesign Initiative (MSCRI) was implemented between 2010 and 2013, and eleven colleges and universities including the research institution described later completed the redesign projects (NCAT). Statewide redesign efforts indicated remarkable educational outcomes with six of the eleven institutions reporting higher student learning outcomes. Course completion rates indicated no changes in seven courses that were redesigned, whereas a significant increase was reported in two courses (NCAT). The research university described below, participated in course redesign efforts by redesigning college algebra through the emporium model in 2012, and reported statistically significant increases in academic achievement in redesigned sections in addition to statistically significant increases in course completion rates (NCAT).

Course Redesign Story of the Research Institution

This research institution which will be called “Urban U” redesigned college algebra which had been taught in a traditional format. The original course had three 50-minute face-to-

face lectures each week and had an average section size of 35-40 students (MSCRI, 2011; 2012). Urban U proposed to increase the students' academic achievement by improving retention rates, and to reduce the cost of instruction by following the pedagogical principles emphasized by NCAT: active student engagement, ongoing practice, immediate feedback and on-demand help (MSCRI). Redesign efforts at Urban U were constructed on three fundamental principles: (a) renovation of the course structure for active student engagement and effective lectures, (b) infusion of the best practices of ILT and technology-supported educational assessment opportunities, and (c) development of an Interactive Math Learning Center (MSCRI). College algebra redesign efforts provided enhanced student involvement in student-centered learning environments, individualized on-demand support to learners, formative assessment and immediate feedback, and on-task learning in college algebra classrooms by redesigning the entire college algebra course (MSCRI). Urban U used the emporium model to redesign its college algebra sections, and stated that "[t]he adoption of the emporium model, with its computer lab format, provides students with a structured and supportive environment in which to practice doing math," (MSCRI, p.4).

Instructional Design and Changes in Course Structure

Course redesign efforts at Urban U targeted college algebra as a whole to minimize the instructional differences between college algebra sections, and to ensure all students enrolled in college algebra sections had similar learning experiences (MSCRI, 2011). Traditional lecturing sections were cancelled and replaced by two mandatory 75-minute interactive lab sections and one 50-minute class meeting. It expected to have approximately 50 students per lab section, whereas approximately 100-150 students were expected in each class meeting (MSCRI, 2011; 2012). The primary instructor, who was full-time faculty, lectured to the large group of students

once a week and covered the important parts of the content as well as selected concepts and topics designed to prepare students for the assessment (MSCRI). Students were required to attend lab sections twice a week and to attend a class meeting once a week. MyLabPlus© which is a learning management system developed by Pearson Education was used to deliver the content online in the interactive learning labs (MSCRI). Instruction and educational practices were built on read, watch, practice and homework components in interactive learning lab sections, and each activity was a prerequisite for the following activity (MSCRI). The class meetings were not for lecturing, or reviewing homework; rather they provided the opportunity for evaluation, screening and facilitating student-student and student-faculty interaction. Students were also introduced to new assessment and feedback opportunities in redesigned courses. Course redesign provided formative assessment and immediate feedback about students' learning process which was supported by individualized assistance from the instructors and tutors (MSCRI).

Physical Learning Environment

Urban U proposed to move the traditional face-to-face teaching and learning experiences to an Interactive Mathematics Learning Center (IMLC) which provided opportunities for learners to be active members of the learning community (MSCRI, 2011). Mayes (2004) summarized that

The focus of the laboratories [IMLC] is on using technology to improve student conceptual understanding, engage students in applying mathematics to solve problems, and improving students' attitudes and beliefs about mathematics. Communities are formed in the laboratory consisting of 25 students mentored by an undergraduate or graduate student. The course coordinator, instructor, or laboratory manager oversees these communities. (p. 66)

The IMLC contained seventeen six-person computer stations, and became a dynamic learning space not only for the students who enrolled in the redesigned college algebra sections, but also other computationally-intensive mathematics courses at Urban U (MSCRI). It was

proposed that “[t]he IMLC will be Urban U’s centralized computer laboratory for mathematical learning, tutelage, and discourse” (MSCRI, p. 5).

Extensive use of ILT

“[Urban U] recognizes that the two key measures of successful course redesign –learning improvement and cost reduction – depend heavily on the strategic leveraging of technology” (MSCRI, 2011, p. 7). The course redesign initiative promised to replace lectures with interactive learning, assessment tasks, and activities (MSCRI). After extensive evaluations based on criteria such as usability of the LMS, assessment and feedback opportunities provided by the LMS, accordance between the components of the LMS, compliance of FERPA and ADA requirements of the LMS, and interviews with previous course redesign investigators, a commercially available online learning and assessment product MyMathLab[®] with corresponding electronic textbook and online supplementary materials published by Pearson[®] was selected as the course redesign LMS platform (MSCRI). MyMathLab was used extensively in lab sections to allow students to interact with the content in an online learning environment. Interactive lab sections offered students opportunities to read content materials, watch tutorials and animations, complete the exercises and work collaboratively in group projects through MyMathLab that supports active student engagement with the course content, course tasks and activities, increases collaboration between peers and provides various assessment and feedback opportunities (MSCRI). Students had access to course materials and assessment tools not only during lab sections, but also outside of the class time through the LMS (MSCRI). Automated delivery of course content and assessment of coursework through the LMS provided students more opportunities such as repeating the activity until succeeding by providing constructive feedback on tasks to master the content (MSCRI). In addition to the LMS, Classroom Response Systems

(CRS) were implemented for on-going assessment and feedback. CRS (Clickers) allowed students to participate in class discussions anonymously and provided immediate feedback on their learning process. CRS also supported instructors with instant feedback on students' performance and with the ability to track attendance electronically (MSCRI). Classroom response systems – clickers- were also used to start discussions, to facilitate active student involvement, and to track attendance (MSCRI).

Conclusion

Turner (2009) stated that “[t]he lecture method is remarkably resistant to change because it appears to be very efficient. What remains a dirty little secret on many campuses is the high percentage of students who do not succeed in this environment” (p. 11). College algebra is one of the courses in which this traditional method has been considered effective teaching for many years. Low academic achievement, high enrollment rates, high attrition rates, lack of students' mathematical preparation, and inconsistent instructional practices are the major problems of college algebra reported by two-year colleges and four-year colleges and universities nationwide. ILT have been implemented both as an enhancement of the way content is delivered and as a remediation effort to minimize undesired student learning outcomes. Calculators, computer-assisted instruction, supplemental instruction and video-supplemental instruction, web-based learning, and integration of LMS are the stepping-stones of technology integration, and ILT are required for better teaching in the context of college level mathematics. Common sense in using technology in mathematics education suggests that integration of technology in mathematics education enhances the learning environment and increases academic achievement at all grade levels although limited research is available in the context of college algebra.

Infusion of ILT into college algebra courses has gained more attention with the development of course redesign models which are created and guided by the National Center for Academic Transformation (NCAT). The NCAT suggests the emporium model, among others, as the best model for course redesign in mathematics instruction. Statewide course redesign initiatives and individual institutional efforts to redesign large enrollment courses are supported by the NCAT, and many of the participating institutions reported positive or equivalent learning outcomes, reduced attrition rates and cost effectiveness in large-enrollment college level courses. Between 2010 and 2013, the Missouri Statewide Course Redesign Initiative (MSCRI) was supported by NCAT, and one of its research universities redesigned its college algebra course by using the emporium model under the scope of this initiative. Several curricular changes were implemented such as incorporating extensive use of LMS and ILT in college algebra courses although the content remained the same as it was in traditional college algebra courses. As a result, Urban U reported improved academic achievement and course completion rates in addition to reduced cost per student in its redesigned college algebra courses. Redesigning college level mathematics courses for better learning outcomes, and higher retention rates is promising, but Twigg (2003c) advised that “transformation is hardwork: it takes a lot of time and effort. It is not something that magically happens by deciding ‘we will be transformed simply by virtue of technology’s existence’” (p. 114).

In conclusion, educational technology has supported mathematics education at all grade levels throughout the history of mathematics. Starting with the use of the abacus, which is widely accepted as the ancestor of modern computer technology, various educational tools and technologies have been used for improving the effectiveness of mathematics instruction. It should be recognized that existence of technology alone cannot make mathematics instruction

better because technology always requires good pedagogy behind it to be effective in educational settings. Not only in mathematics education, but also in all disciplines and grade levels, blending the best practices of pedagogy with the best use of educational technology is optimal for improved learning outcomes. This is exactly what the National Center for Academic Transformation has been trying to do for more than a decade, and it has been highly successful leveraging college-level mathematics education with a heavy use of educational technology.

CHAPTER 3

MEASUREMENT OF PSYCHOSOCIAL FACTORS OF LEARNING IN THE MATH
EMPORIUM: SCALE DEVELOPMENT AND ASSESSMENT

Abstract

The scale, Psychosocial Factors of Learning in Redesigned Introductory College Mathematics (PFL-RICM), was designed to measure students' attitudes toward mathematics, motivation to learn mathematics, and satisfaction with the instructional design in redesigned college level mathematics courses. Attitudes and beliefs along with motivation have been widely studied in mathematics education especially in K-12, but the research is limited at higher education levels. Attention has also been widely paid to traditional instructional settings, but not to technology-supported redesigned learning environments. Currently available instruments are limited to considering how technology integration influences instructional practices that directly or indirectly impact the psychosocial factors of learning. PFL-RICM was developed considering the technology-supported course redesign efforts in college-level introductory mathematics courses. This paper reports the reliability, and validity evidences of the scale. The final form of the scale includes three sub-scales, and consists of 38 items which are loaded under eight different factors. The Cronbach's Alpha internal consistency reliability coefficients were at desired level, except for one sub-scale. Although PFL-RICM was developed for redesigned college mathematics settings, it is a reliable and valid instrument that can be used in K-12 mathematics education in which technology is extensively integrated.

Introduction

Technology-supported course redesign efforts guided by the National Center for Academic Transformation (NCAT) have changed the way college level introductory courses have been taught for more than a decade (NCAT, 2015g). From college algebra to introductory psychology, several courses have been redesigned nationwide by extensively utilizing instructional and learning technologies (ILT). The underlying notion behind the course redesign models is to increase academic achievement and retention rates while reducing the cost of instruction by manipulating the pedagogical dynamics of the traditional face-to-face teaching approach, and by comprehensively integrating ILT into educational practices. Although all course redesign models serve the same purposes, each model emphasizes different aspects of instructional practices and associated ILT integration.

The NCAT (2015e) proposed six models of course redesign: supplemental; replacement; fully online; the buffet; linked workshop; and the Emporium to remediate developmental and college level introductory courses, which suffer from high enrollment and failure rates. Twigg (2003b) summarized that the *supplemental model* focuses on technology-based and off-campus supplemental activities while retaining the traditional model of instruction whereas the *replacement model* uses a blended mode of instruction by replacing part of the in-class meetings with online instructional practice along with remediating the remaining in-class meetings. The instructional model that eliminates all face-to-face meetings and moves all instructional practices to the virtual settings is called *the fully online model*. *The buffet model*, on the other hand, offers an individualized learning path for students to achieve the same learning goals and objectives by considering their educational needs and expectations. The buffet model ignores one-size-fits-all approach, and customizes the learning context for each student by offering various learning

opportunities. The Ohio State University, for example, implemented the buffet model for an introductory statistics course, and offered lectures, face-to-face and online individual or group discovery laboratories, individual and group review, study, video, remedial procedure training sessions, individual or group projects and presentations, active large group problem solving and homework assignments, so that students were able to choose their own learning path based on their educational preferences and goals. *The linked workshop model* focuses on remedial and developmental instruction which is built on linked workshops that provides timely academic support, whereas *the Emporium model* replaces in-class meetings with learning resource centers which are fully equipped computer labs that allow students to work collaboratively, to receive immediate feedback, and to get on-demand assistance.

The pedagogical outcomes of each model hold promise for increasing academic achievement by reducing failure and withdrawal rates, and reducing the cost of instruction in redesigned courses including college level introductory mathematics courses. Participating institutions, in general, have reported successful course redesign outcomes, and many have retained the course redesign efforts with minor changes after pilot implementation. Nationwide, the positive outcomes of the course redesign projects include increased academic achievement and retention of discipline-specific content knowledge, enhanced engagement and interaction in learning settings, increased enrollment and retention rates, improved faculty and student satisfaction, changes in attitudes toward subject matter, and reduced cost (Johnson, McAlpin, & An, 2012; Rosenthal & Weitz, 2012). In addition to these outcomes, some institutions report increased student motivation (e. g. Tallahassee Community College). However, empirical research on the psychosocial factors of learning is limited, perhaps due to the lack of best-match measurement tools which focus on: specific course redesign efforts, possible impact of

technology use, and modified instructional design in redesigned college level introductory mathematics courses.

Various instruments that focus on K-12 mathematics learning have been developed to assess students' motivation to learn in mathematics, attitudes toward mathematics, satisfaction from the instruction in mathematics, and student perceptions toward technology integration (see Conley & Karabenick, 2006; Davis, 2014; Fennema & Sherman, 1976; Githua & Mwangi, 2003; Keengwe, 2007; Pierce, Stacey, & Barkatsas, 2007; Savery, 2002; Tapia & Marsh, 2004; Wu, Tennison, & Hsia, 2010). However, none of the instruments that focus on psychosocial factors of learning was specifically developed by considering the fundamental principles of course redesign models although some of them can be adapted to some degree. Also, the researcher consulted with experts in the fields of mathematics, mathematics education, and educational psychology and concluded that there is a need to develop a new instrument because of the pedagogical dynamics of the course redesign in college level introductory mathematics education.

Redesigned settings require target-driven attitude, motivation and satisfaction items to address the core elements of course redesign such as immediate feedback opportunities or extensive use of ILT in addition to commonly-accepted attitude, motivation, and satisfaction items which focus on traditional mathematics education settings. Current attitude, motivation, and satisfaction scales focus heavily on traditional educational settings, and pedagogical practices in K-12 mathematics contexts. Items that are designed to measure the effects of major changes in overall course structure on those variables are not available in current instruments. The PFL-RICM scale was developed based on the underlying pedagogical principles of the Emporium model, which requires extensive technology integration along with significant change in instructional practice from a teacher-centered approach to a student-centered constructivist

approach. The main goal of the scale is to address the need for an instrument that combines course redesign efforts, technology integration, and psychosocial factors of learning in college-level mathematics education literature. In addition, the instrument can be used in K-12 mathematics education settings in which instructional technology is an essential and major part of the regular educational practices.

Literature Review

Under the influence of the course redesign movement, college-level mathematics education has transformed from a traditional approach to a student-centered constructivist approach through extensive use of technology for more than a decade. This transformation was not an option, but a must. Small (2006) called for an urgent transformation specifically for college algebra courses which affected thousands of students annually. Indeed, the story is not different for other college level introductory courses, which are known for high student enrollments, low academic achievement, and low retention rates. Many course redesign efforts facilitate this transition by offering solutions to the problems of college level introductory courses. Technology integration, for example, is an essential component of course redesign efforts, facilitating the implementation of the best pedagogical practices with large numbers of students (Twigg, 2003a). A growing number of institutions have participated in the course redesign movement to combine the best practices of pedagogy with the best practices of instructional technology. Although one gains strength from the other, it should be noted that “good pedagogy in itself has nothing to do with technology” (Twigg, 2003a, p. 27).

The definition of good pedagogy is subjective, but it is commonly accepted that good pedagogy has potential to improve student learning outcomes. Coe, Aloisi, Higgins, and Major (2014) stated that “[u]ltimately, the definition of effective teaching is that which results in the

best possible student outcomes. There is currently no guaranteed recipe for achieving this: no specifiable combination of teacher characteristics, skills and behaviours consistently predicts how much students will learn” (p. 46-47). Coe et al. also listed six components of good teaching as pedagogical content knowledge, quality of instruction, classroom climate, effective classroom management, teacher beliefs and professional behaviors by noting that pedagogical content knowledge and quality of instruction have strong evidence of impact on student outcomes. As a result of course redesign efforts, a high number of participating institutions report increased academic achievement and retention rates (see Twigg, 2005). However, the question of ‘how this happens?’ remains unanswered. Increased academic achievement or retention in redesigned settings can neither be solely attributed to technology integration nor to changes in instructional practices. However, these efforts impact some mediating factors which potentially trigger academic achievement and retention rates in the redesigned learning settings. The mediating factors that contribute to academic success should be examined carefully in redesigned settings to understand how course redesign efforts influence student learning outcomes.

Robbins, Lauver, Le, Davis, Langley and Carlstrom (2004) identified three types of determinants of academic achievement in college settings: traditional, demographic and psychosocial. According to Krumrei-Mancuso, Newton, Kim, and Wilcox (2013), in college settings, psychosocial factors are influential predictors of college retention and GPA after controlling for traditional determinants such as incoming mathematics knowledge. Students’ motivation to learn, attitudes toward subject matter, and satisfaction from the learning settings can be grouped under the psychosocial predictors of academic success. Although academic achievement and retention might not be directly explained by major course redesign efforts, technology integration and major changes in instructional design potentially affect the

psychosocial factors of learning which should be considered as some of the mediator variables between course redesign efforts and course redesign outcomes.

Attitudes Toward Mathematics

Attitudes toward mathematics has been widely studied in educational settings for a long time despite the fact that the concept itself needs to be developed theoretically (Hannula, 2002; Zan & Di Martino, 2007). There is no single definition of attitudes toward mathematics that everyone agrees on. According to Kulm (1980), a common definition of attitudes toward mathematics might not be appropriate for all situations and might be too general to be useful. Hannula introduced basic notion of attitude as "...someone's basic liking or disliking of a familiar target" (p. 25), whereas Aiken (1970) defined attitudes as "a learned predisposition or tendency on the part of an individual to respond positively or negatively to some object, situation, concept, or another person" (p. 551). General definitions of attitude reflect on specific definitions of attitudes toward learning mathematics.

According to Neale (1969) the definition of attitudes toward mathematics is not definite, but tools developed to measure it include items that emphasize "a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at Mathematics, and a belief that Mathematics is useful or useless" (p. 632). Zan and Di Martino (2007) grouped definitions of attitudes toward mathematics under three categories which include (a) simple definition that defines attitude towards mathematics as "just a positive or negative emotional disposition toward mathematics" (McLeod, 1992; Haladyna, Shaughnessy, & Shaughnessy, 1983 as cited in Zan & Di Martino, p. 158); (b) a multidimensional definition which "defines attitudes toward mathematics in a more complex way by the emotions that he/she associates with mathematics (which, however, have a positive or negative value), by the

individual's beliefs toward mathematics, and by how he/she behaves" (Hart, 1989 as cited in Zan & Di Martino, p. 158); (c) a bi-dimensional definition which defines attitudes toward mathematics as the pattern of beliefs and emotions associated with mathematics because behaviors do not appear explicitly (Daskalogianni & Simpson, 2000, as cited in Zan & Di Martino, p. 158).

The PFL-RICM scale adopts the simple definition of attitude and the extended definition of attitudes toward mathematics proposed by Ma and Kishor (1997). Therefore, in developing items, more attention was paid to including feelings such as like or dislike, having anxiety and/or fear, feeling happiness, showing positive reaction and behavior, enjoyment etc. in survey items. Thus, statements such as "I approach math with a feeling of hesitation, resulting from a fear of not being able to do math" or "Mathematics is very interesting to me" were added to the attitude section of the PFL-RICM scale. In addition, statements such as "I like to work out problems in mathematics by myself"; "I think I will do better in mathematics courses if interactive learning activities are used"; "I would be happy if my learning process were evaluated in a prompt and continuous manner throughout the mathematics course"; "Using technology for learning mathematics can be a little scary" and "If I use technology in mathematics, I will not learn as well" were included in the PFL-RICM scale to evaluate the role of course redesign dynamics on students' attitudes toward mathematics under the light of the extended definition of attitudes toward mathematics.

Motivation to Learn Mathematics

Motivation has been widely studied in school contexts for a long time although it, too, is difficult to define (Waugh, 2002). According to Gardner (2007), a simple definition of motivation cannot be proposed because there might be many different characteristics which

might possibly be cognitive, affective and/or behavioral in nature. Graham and Weiner (1996) defined motivation as “the study of why people think and behave as they do” (p. 63) whereas Middleton and Spanias (1999) stated that “motivations are reasons individuals have for behaving in a given manner in a given situation” (p. 66). Motivation is a comprehensive and complex variable which might have different determinants in different contexts. In educational settings, motivation, student motivation, and motivation to learn are often used interchangeably although they are different, but related terms. According to Lumsden (1994), a basic definition of student motivation is the learners’ desire which is also guided by underlying reasons or goals of their involvement in the learning process. Brophy (1987) believed that motivation to learn can be explained (a) as a general trait which refers to the continuous tendency to value learning processes as meaningful, worthwhile and satisfactory, and (b) as a situation-specific state of motivation to learn that “...exists when task engagement is guided by the goal or intention of acquiring the knowledge or mastering the skill the task is designed to teach” (pp. 181-182).

Two different types of motivation to learn are studied in educational settings: extrinsic and intrinsic motivation. According to Middleton and Spanias (1999), extrinsic motivation is nurtured by external rewards or avoidance of punishment whereas intrinsic motivation is the wishfulness of participating in learning activities for the learners’ willingness. Both extrinsic motivation and intrinsic motivation have been studied in mathematics education. In a literature review study, Middleton and Spanias conclude that (a) learner perceptions of academic achievement in mathematics affect learners’ motivational attitudes; (b) teacher actions and attitudes are influential on motivation towards mathematics which are developed early, and consistent over time; (c) opportunities provided to develop intrinsic motivation towards mathematics surpass opportunities provided to develop extrinsic motivation; (d) the way learners

are taught to value mathematics varies among different learner groups; and (e) motivation to succeed in learning mathematics can be influenced by instructional design.

Course redesign as a new approach to instructional design changes the dynamics of traditional instructional practices by incorporating ILTs into learning processes. It is most likely to impact students' motivation to learn mathematics in redesigned settings. Twigg (2009) emphasized the role of motivation in redesigned settings by stating that “[m]otivation to learn, in turn, was significantly related to course outcomes (satisfaction, metacognition, and grades)” (p. 2). In order to better understand the impact of course redesign efforts on learners' motivation to learn mathematics, several items that specifically address course redesign elements were included on the PFL-RICM scale. For that purpose, items such that “[t]he mathematics I learn is more important to me than the grade I received”; “I like to perform better than other students on mathematics tests”; or “My previous experiences with the use of learning technologies in mathematics education increase my motivation to learn mathematics” were included on the PFL-RICM scale.

Satisfaction from Mathematics Instruction.

According to Keller's (1983) ARCS model, attention, relevance, confidence and satisfaction are “must-have” conditions in learning contexts for persistent learner motivation. The latter, student satisfaction, is considered as an important factor, but not a well-studied variable in educational settings, except for online instruction. Lorenzo (2012) reported that learners particularly who have busy schedules, and who are working adult learners are satisfied with online learning/teaching practices because of self-paced learning practices, convenience, and flexibility. Although there are different factors that might impact students' satisfaction in educational practices, learners' computer anxiety, instructor's attitudes toward online learning,

perceived flexibility, quality, and usefulness of the course, ease of use of technology, and variety of assessments were identified as essential factors that affect learners' perceived satisfaction in online learning settings (Lorenzo; Sun, Tsai, Finger, Chen, & Yeh, 2008). Because of extensive technology integration, the Emporium model has similarities with online learning settings. Opportunities such as flexibility, convenience and variety of instructional practices offered by the Emporium model most-likely impact student satisfaction in technology-enhanced mathematics learning settings.

Improved end of semester faculty evaluations, lowered failure (D, F) and withdrawal (W) rates, long term student success rates were used to evaluate student satisfaction in educational settings in the high risk course redesign initiative of Portland State University (Jhaj, n.d.). Although those variables are most likely influenced by student satisfaction, they might not fully explain why learners are satisfied. Thus rather than considering outcomes of the learning process as proof of learner satisfaction, principles of instructional design, pedagogical factors and instructional practices should also be evaluated as determinants of student satisfaction in educational contexts. According to Twigg (2003a; 2003b) interaction with faculty and peers, immediate feedback, on demand help, continuous support, variety of assessment methods, and working as groups are the predictors of student satisfaction in redesigned settings. The PFL-RICM Learner Satisfaction subscale includes items that emphasize such pedagogical components of the Emporium redesign model. The purpose of these items is to evaluate the impact of technological and pedagogical changes in mathematics instruction on learner satisfaction. These items include, but are not limited to “I am satisfied with the overall quality of teaching experiences in mathematics classrooms”; “I am satisfied with the overall quality of immediate feedback opportunities in mathematics; “I am satisfied with the interactive group activities in

mathematics classrooms”, and “I am satisfied with the accessibility of course materials outside of class”.

In conclusion, Psychosocial Factors of Learning in Redesigned Introductory College Mathematics (PFL-RICM) scale was originally developed as part of the Learners’ Perceptions of Redesigned College Mathematics (LP-RCM) scale. In the scope of this paper, three subscales: attitudes toward mathematics, motivation to learn mathematics, and satisfaction from the mathematics instruction that form PFL-RICM scale were analyzed. Extensive literature review on measured variables, and instructional practices used in the Emporium model guided the item development process. The following sections discuss validity and reliability of the PFL-RICM scale, and summarize content validity, face validity, respondent process validity evidences and arguments collected at the time of the PFL-RICM scale development. Internal structure validity and internal replicability analyses were completed through exploratory factor analysis (EFA) and reported separately under the methodology section along with Cronbach’s Alpha internal consistency reliability coefficients.

Discussion of Validity Evidences

Furr and Bacharach (2014) provide a simple definition of validity as “the degree to which a test measures what is it supposed to measure” (p.168). Various validity evidences and arguments that are grouped under an inclusionary term, construct validity, should be collected to make such an evaluative decision. Construct validity is defined as “...an overall evaluative judgment of the degree to which empirical evidence and theoretical rationales support the adequacy and appropriateness of interpretations and actions on the basis of test scores or other modes of assessment” (Messick, 1989, as cited in Nolan, Beran, & Hecker, 2012, p. 13), and it refers to all types of validity evidences and arguments such as content validity, face validity,

respondent process validity, and internal structure validity in psychology and educational research.

Content Validity/Face Validity

Content validity refers to the scope of the content addressed by an instrument to assess a specific domain. In other words, it is about how the items stated in an instrument sample the content that it is supposed to measure. The best way to collect content validity evidences is to ask for professional help or help from someone who has expertise in the content of the questionnaire (Furr & Bacharach, 2014). Content related evidence also includes the format of the instrument. The components of the format can be listed as font size, clarity of prints, clarity of descriptions, clarity and understandability of the items etc. Content validity evidences were collected by collaborating with the four different experts who have been teaching graduate and undergraduate level courses and have published in the fields of mathematics, mathematics education, and counseling and educational psychology. Face validity evidences, on the other hand, were collected by getting feedback from the individuals who have little or no expertise with the domains measured (Furr & Bacharach). The instrument was presented several times to graduate students, faculty, and people who were working at the Institutional Research and Planning (IRAP) Office, and their feedback at the time of questionnaire development was considered.

Response Process Validity Evidence

Psychologically, it is expected that the participants read the items, evaluate their experiences, judge, and choose the option which is more appropriate to them. However it is possible to have some participants who do not read the instructions or items and respond randomly. In order to prevent this random responding and collect evidence of response processes validity, three random responding control items were included in Learners' Perceptions of

Redesigned College Mathematics (LP-RCM) scale. The purpose of those items is to check the attention paid by the participants to instrument stems. These control items have fixed responses. The first item asks participants to mark option B, second C, and the last one asks them to mark option D. If any of the participants chose something different than required for these items, their responses were eliminated from the dataset. In total, 23 participants were excluded because of not paying attention to survey items. The final form of the PFL-RICM scale had two random responding control items.

Internal Structure Validity

Method

This research study protocol and data collection process were approved by the Institutional Review Board (IRB) of the research institution.

Sampling

Convenience sampling process was used, and all students enrolled in all college algebra sessions in the Fall 2011 and Spring 2012 semesters at one of the Midwest research universities (Urban U) were invited to participate in the study on a voluntary basis. The total number of undergraduate students who participated in the study and completed the scale was 345. However, the number of participants reduced to 242 because of incomplete data and random responding control items. In detail, out of 345 participants, 38 were removed because of incomplete data; 12 were removed because of random response control item #1; one participant was excluded because of random response control item #2; ten participants were removed because of random response control item #3; and 42 participants were excluded because of 'Not Applicable' responses. The total number of participants remaining was 242. The data set ($N=242$) was randomly divided into two separate data sets for two phases of data analyses: internal structure

validity analyses, and internal replicability analyses of the scale developed as a result of Phase 1. The first set of data ($N=121$) was used in initial Exploratory Factor Analysis (EFA) analyses (Phase 1) that include individual EFAs of attitudes toward mathematics, motivation to learn mathematics and satisfaction from the mathematics learning experiences subscales. Internal replicability EFA (Phase 2) was completed over data set #2 ($N=121$) with the identical EFA preferences. The results of the KMO and Bartlett's Test of Sphericity were examined in advance to check the appropriateness of the samples for EFA analyses. Sample size-item ratios, KMO, and Bartlett' Test of Sphericity results are presented in Table 1.

Table 1.
Sample Size-Item Ratios

	Subscales	Number of Items	Item/Sample ratio	KMO	Bartlett's Test of Sphericity
Phase 1	Attitude	19*	1:6	.85	$\chi^2(171) = 1250.06, p < .05$
	Motivation	10	1:12	.70	$\chi^2(45) = 208.63, p < .05$
	Satisfaction	17	1:7	.82	$\chi^2(136) = 752.02, p < .05$
Phase 2	Attitude	17	1:6	.81	$\chi^2(136) = 1035.65, p < .05$
	Motivation	6	1:20	.69	$\chi^2(15) = 89.14, p < .05$
	Satisfaction	12	1:10	.76	$\chi^2(66) = 451.48, p < .05$

Note: Three items were removed to address multicollinearity from the attitude scale.

Instrumentation

PFL-RICM scale was originally developed as part of the Learners' Perceptions of Redesigned College Mathematics (LP-RCM) scale which was drafted as 64 items after a comprehensive literature review that covered course redesign with an emphasis on the Emporium model, technology integration in mathematics education attitudes and beliefs about learning

mathematics, motivation to learn mathematics and satisfaction from the college level courses. At the time of item development, expert opinions were sought regarding (a) whether the scale and items were appropriate, significant and sufficient; and (b) whether the number of items was sufficient to measure the purposed variables for the sake of validity. As a result, five items were identified as double-barreled, and three items were recommended to be restated because of technical terms and being confusing to students who do not have certain technology resources available in the classroom. To address all these concerns, confusing items were restated; technical terms were excluded or replaced; grammatical or technical mistakes were fixed; and five new items were added to the survey after double-barreled items were separated. In addition, required options of random responding control items were changed from A and F to B, C and D to minimize the likelihood of random guessing to find correct options of control items.

As a result, the LP-RMI survey consisted of 74 items that include three random responding control items, three multiple choice descriptive items, and five self-evaluation items. In total, the scale has six intended subscales: attitudes toward mathematics, motivation to learn mathematics, satisfaction from the mathematics instruction, technology-supported interactive classroom settings in mathematics education, college algebra self-evaluation scale, and instructional technology applications and practices in mathematics education. In the scope of this paper, 22 items that targeted attitudes toward mathematics, 10 items that targeted motivation to learn mathematics, and 17 items that targeted satisfaction from the mathematics instruction were analyzed through exploratory factor analyses and internal replicability analysis.

Rationale

Osborne (2014) clarifies that the purpose of the EFA is to extract latent factors from the measured variables by examining all pairwise relationships between individual variables whereas

principal component analysis (PCA) does not consider the underlying latent structure of the variables. Thus, EFA was preferred to PCA for the analysis of internal structure validity. Preliminary descriptive analysis on data set 1 ($N=121$) indicated that data were normally distributed, with skewness of .09 ($SE = .22$), kurtosis of -.21 ($SE = .44$), and Shapiro-Wilk tests of normality ($S-W = .99$, $df=121$, $p = .963$) indicated that the data distribution did not significantly deviate from a normal distribution. Likewise, preliminary descriptive analysis on data set 2 ($N=121$) concluded that data were also normally distributed with skewness of .07 ($SE = .22$), kurtosis of .04 ($SE = .44$), and non-statistically significant Shapiro-Wilk tests of normality ($S-W = .99$, $df=121$, $p = .982$).

Maximum Likelihood was used as extraction method because Fabrigar, Wegener, MacCallum and Strahan (1999) suggested that maximum likelihood is the best choice when data are relatively normally distributed (as cited in Osborne, 2014). Latent constructs tend to be marginally correlated -particularly subscales that are part of the same instrument- in most disciplines including the social sciences (Osborne, 2014). Because marginal correlation among extracted factors was theoretically assumed while deciding the extraction method, oblique rotation methods were considered, and specifically the Promax rotation method that is recommended by Thompson (2004) was chosen for EFA analyses. According to Osborne (2014), evaluation of the Kaiser Criteria, and scree plot in conjunction is desired to decide the number of factors that should be extracted and retained. Both the Kaiser Criteria which accepts an eigenvalue greater than 1.0 is a good indicator of a meaningful factor, and natural bends on a Scree plot were analyzed to decide the number of factors that should be extracted and retained. Finally, examination of the R-Matrix for multicollinearity and singularity indicated that there was no multicollinearity for the motivation ($D=.165$) and satisfaction ($D=.001$) subscales, but

multicollinearity was a problem for the attitudes subscale ($D=6.201E-8$), so three highly correlated attitude items ($r>.85$) were excluded to address this issue. Multicollinearity was not an issue for the replicability EFA analyses.

Results

Phase 1: Initial Exploratory Factor Analysis

Initial EFA analyses for attitudes toward mathematics, motivation to learn mathematics, and satisfaction from the learning experiences were grouped under Phase 1. Items that had low loadings, and cross-loadings were included/excluded stepwise by considering the repeated EFA analysis results to find the best-fit. Maximum Likelihood extraction, and oblique (Promax) rotation methods were used as standard preferences in all EFA analyses. Chi-squared goodness-of-fit statistics were also reported.

Attitudes Toward Mathematics Subscale

The factorability of 22 attitudes toward mathematics items were examined through exploratory factory analysis. Examination of the correlation matrix and the determinant indicated multicollinearity, and three highly correlated items ($r>.85$) were removed from the EFA analysis. Initially, EFA was run with 19 items. The Kaiser Criterion of eigenvalues and the Scree plot showed that 19 items were grouped under three latent factors. The eigenvalues suggested that the first factor explains 27% of the variance, the second factor 19% of the variance and the last

Table 2.

PFL-RICM ATM subscale Item Stems, Components, Coefficients, and Communalities for Phase 1 (N = 121)

Item Stem	Factors ^{ab}			h^2
	1	2	3	
I feel a definite positive reaction to mathematics; it's enjoyable.	.91 (.89)	-.06 (.01)	.10 (-.03)	.81
I have always enjoyed studying mathematics.	.88 (.86)	-.03 (.05)	.14 (.02)	.76
I am happier in a mathematics class than in any other class.	.84 (.84)	-.06 (.09)	-.05 (-.17)	.71
Mathematics is very interesting to me.	.82 (.80)	-.02 (-.03)	.18 (.06)	.67
I approach mathematics with a feeling of hesitation, resulting from a fear of not being able to do math.	.81 (.84)	.08 (.07)	-.17 (-.26)	.74
I prefer to avoid mathematics classes, if possible.	.81 (.80)	.04 (.11)	.08 (-.02)	.65
I feel comfortable with the delivery methods of course content in mathematics courses.	.58 (.61)	.11 (.10)	-.18 (-.24)	.41
Using technology increases my proficiency in mathematics.	.51 (.54)	.03 (.00)	-.25 (-.31)	.35
Using technology stimulates my interest in mathematics.	-.02 (.01)	.83 (.85)	.08 (.25)	.72
Technology-supported mathematics education helps me to learn mathematics better.	-.07 (-.05)	.75 (.78)	.17 (.34)	.65
I like mathematics that challenges me.	-.05 (-.00)	.75 (.74)	-.02 (.14)	.55
Using technology for learning mathematics can be a little scary.	.09 (.16)	.70 (.65)	-.24 (.20)	.49
If I use technology in mathematics, I will not learn as well.	.04 (.06)	.66 (.67)	.08 (-.11)	.46
Using technology gets in the way of learning mathematics.	.08 (.11)	.54 (.54)	-.02 (.09)	.30
I think I will do better in mathematics courses if interactive learning activities are used.	.01 (-.10)	.02 (.18)	.78 (.79)	.62
I wish I had more opportunities to engage in collaborative learning activities in class.	-.03 (-.13)	.08 (.24)	.76 (.78)	.62
I would be happy if my learning process were evaluated in a prompt and continuous manner throughout the mathematics course.	.05(-.04)	-.05 (.08)	.62 (.61)	.37

Note: Factor loadings < .4 are suppressed. 1 = attitudes towards mathematics 2 = attitudes towards technology-supported mathematics 3 = beliefs about learning mathematics

a. Component correlations were as follows: $r_{12} = .06$, $r_{13} = -.13$, and $r_{23} = .21$

b. Pattern coefficients are followed by structure coefficients in parentheses.

factor 9% of the variance. The pattern matrix and the structure matrix indicated that items “I like to work out problems in mathematics by myself” and “I believe online support / communication from my instructor might increase the quality of learning” were cross-loaded and/or failed to meet minimum criteria of having a primary factor loading of .40, so these items were removed.

Final EFA analysis was completed with 17 items. The Kaiser Criteria and Scree plot suggested three-factor structure: Factor 1, attitudes toward mathematics, explained 29% of the variance; Factor 2, attitudes toward technology-supported mathematics, explained 19% of the variance; and Factor 3, learners’ beliefs about learning mathematics, explained 10% of the variance. As a result, the three-factor structure with $\chi^2(88, N = 121) = 122.953, p < .05$ that explained 58% of the variance in total was retained. The factor loading matrix is presented in Table 2.

Motivation to Learn Mathematics Subscale

The factorability of 10 motivation to learn mathematics items was tested through EFAs. Examination of the correlation matrix and the determinant indicated no multicollinearity. Examination of the Kaiser Criteria of eigenvalues and the Scree plot revealed a three-factor structure. The initial eigenvalues suggested that the first factor explains 16% of the variance, the second factor explains 18% of the variance, and third factor explains 6% of the variance. The pattern matrix and the structure matrix showed that four items, which were “My previous experiences with the use of learning technologies in mathematics education increase my motivation to learn mathematics”; “I think about how learning mathematics might affect my future career”; “I am confident I will do my best in mathematics”; and “Understanding mathematics gives me a sense of accomplishment” were cross-loaded and/or failed to meet minimum criteria of having a primary factor loading of .35, so these items were excluded. Final

EFA analysis was completed with six items. The Kaiser Criteria and the scree plot suggested a two-factor structure: Factor 1, intrinsic motivation, explained 28% of the variance and Factor 2, extrinsic motivation, explained 9% of the variance. As a result, a two-factor structure with $\chi^2(4, N = 121) = 5.303, p > .05$ that explained 37% of the variance in total was retained. The factor loading matrix is presented in Table 3.

Table 3.
PFL-RICM MLM subscale Item Stems, Components, Coefficients, and Communalities for Phase I (N = 121)

Item Stem	Factors ^{ab}		
	1	2	h^2
The methods used in mathematics education affect my motivation.	.75 (.71)	-.08 (.29)	.51
I have to study harder than my classmates to understand mathematics concepts.	.76 (.75)	-.01 (.37)	.57
The mathematics I learn is more important to me than the grade I receive.	.36 (.49)	.28 (.45)	.30
I like to perform better than other students on mathematics tests.	-.09 (.21)	.61 (.56)	.32
I feel more motivated when I receive immediate feedback.	-.01 (.24)	.51 (.50)	.25
Earning a good mathematics grade is more important to me than understanding the concepts.	.17 (.37)	.39 (.48)	.26

Note: Factor loadings < .35 are suppressed. 1 = intrinsic motivation 2 = extrinsic motivation

a. Component correlation was $r_{12} = .49$,

b. Pattern coefficients are followed by structure coefficients in parentheses.

Learner Satisfaction Subscale

Seventeen learner satisfaction items were analyzed through EFAs to reveal underlying factors. The correlation matrix and the determinant indicated no multicollinearity. Analysis of the Kaiser Criteria of eigenvalues and the scree plot showed a four-factor structure. The initial

eigenvalues suggested that the first factor explains 30% of the variance, the second factor explained 8% of the variance, the third factor explained 6% of the variance, and the fourth factor explained 4% of the variance. The pattern matrix and the structure matrix revealed five items: “I feel satisfied if I get immediate feedback about my assignments”; “I am satisfied with the assessment methods of mathematics courses”; “I am satisfied with the instructor’s efforts to teach mathematics content”; “I will encourage my colleagues to take mathematics classes in their future academic careers”, and “I am satisfied with the quality of mathematics textbooks” were either cross-loaded and/or failed to meet minimum criteria of having a primary factor loading of .40, so these items were excluded. Final EFA analysis was run with 12 items. The Kaiser Criteria and Scree plot suggested a three-factor structure: Factor 1, satisfaction from mathematics instruction, explained 15% of the variance; Factor 2, satisfaction from course redesign efforts, explained 28% of the variance; and Factor 3, overall satisfaction from the mathematics learning experiences, explained 7% of the variance. As a result, a three-factor structure with $\chi^2(33, N = 121) = 55.844, p < .05$ that explained 50% of the variance in total was retained. The factor loading matrix is presented in Table 4.

Phase 2: Internal Replicability Analysis

The EFA analyses for internal replicability were grouped under Phase 2. All EFA analyses were completed over data set #2 with Maximum Likelihood extraction and oblique (Promax) rotation methods. Internal replicability analyses were completed by considering two criteria claimed by Osborne and Fitzpatrick (2012) for successful replication analysis: (a) loading of items to the same factors, configural invariance, and (b) equivalency of item factor loadings, structural invariance (the difference should be less than |.20|) in magnitude in both analyses. Chi-squared goodness-of-fit statistics were also reported.

Table 4.

PFL-RICM LS subscale Item Stems, Components, Coefficients, and Communalities for Phase I (N = 121)

Item Stem	Factors ^{ab}			
	1	2	3	h^2
I am satisfied with the methods used to deliver course content in mathematics courses.	.90 (.83)	-.12 (.41)	.06 (.12)	.70
I am satisfied with the overall quality of teaching experiences in mathematics classrooms.	.78 (.72)	-.10 (.55)	.03 (.10)	.52
Mathematics instruction needs to be improved.	.67 (.76)	.16 (.35)	.02 (.07)	.60
I am satisfied with my mathematics content proficiency (knowledge).	.60 (.63)	.07 (.40)	-.10 (-.04)	.41
The mathematics instruction I have had so far causes me to question my mathematics ability.	.48 (.52)	.05 (.36)	.14 (.19)	.30
I am satisfied with the opportunities I have to participate and share my ideas during class activities.	.10 (.52)	.75 (.78)	-.10 (.05)	.63
I am satisfied with the accessibility of course materials outside of class.	-.11 (.30)	.70 (.65)	.10 (.22)	.44
I am satisfied with the accessibility of course grades outside of class.	-.12 (.21)	.56 (.52)	.13 (.22)	.30
I am satisfied with the interactive group activities in mathematics classrooms.	.16 (.46)	.55 (.61)	-.14 (-.02)	.41
I am satisfied with the overall quality of immediate feedback opportunities in mathematics.	.25 (.50)	.44 (.58)	.03 (.13)	.38
Greater use of learning technologies in the mathematics classroom might increase my overall satisfaction with mathematics courses.	-.06 (.07)	.08 (.22)	.95 (.96)	.93
I am satisfied with the overall quality of my formal mathematics experiences.	.18 (.21)	-.03 (.17)	.56 (.57)	.35

Note: Factor loadings < .4 are suppressed. 1 = satisfaction from mathematics instruction, 2 = satisfaction from course redesign efforts, 3 = overall satisfaction from the mathematics learning experiences.

a. Component correlations were as follows: $r_{12} = .58$, $r_{13} = .08$, and $r_{23} = .19$

b. Pattern coefficients are followed by structure coefficients in parentheses.

Attitudes Toward Mathematics Subscale

Seventeen attitudes toward mathematics items were reexamined through EFAs. The Kaiser Criteria of eigenvalues and the scree plot explained that 17 items were grouped under three latent factors. The initial eigenvalues suggested that the first factor explained 27% of the variance, the second factor explained 18% of the variance and the last factor explained 8% of the variance. As a result, three-factor solution with $\chi^2(88, N = 121) = 134.357, p < .05$ that explained 53% of the variance was selected based on the eigenvalues and natural bends on the scree-plot. Internal replication analysis for the PFL-RICM attitudes toward mathematics (ATM) concluded that same items were loaded under the same three latent factors in both analyses, and equivalency of item factor loading were at desired level. Only one item, “[u]sing technology for learning mathematics can be a little scary”, failed to meet the criterion of having equivalent item factor loadings. The item was retained although the difference between its factor loadings (.24) was slightly higher than cutoff point (.20) suggested by Osbourne and Fitzpatrick (2012). The item was not excluded because it directly addresses the impact of technology on student attitudes, but it is recommended to watch for this item in future implementations. The factor loading matrix of replication analysis of PFL-RICM ATM subscale is presented in Table 5.

Table 5.

PFL-RICM ATM subscale Replication Analysis Item Stems, Components, Coefficients, and Communalities for Phase 2
($N = 121$)

Item Stem	Factors ^{ab}			
	1	2	3	h^2
I feel a definite positive reaction to mathematics; it's enjoyable.	.90 (.89)	.04 (.14)	.08 (-.06)	.80
I have always enjoyed studying mathematics.	.81 (.82)	-.00 (.05)	-.10 (-.23)	.69
I am happier in a mathematics class than in any other class.	.85 (.84)	-.05 (.03)	.04 (-.11)	.70
Mathematics is very interesting to me.	.83 (.81)	-.06 (.04)	.11 (-.04)	.67
I approach mathematics with a feeling of hesitation, resulting from a fear of not being able to do math.	.76 (.77)	.02 (.08)	-.05 (-.17)	.60
I prefer to avoid mathematics classes, if possible.	.73 (.73)	.00 (.07)	.00 (-.12)	.53
I feel comfortable with the delivery methods of course content in mathematics courses.	.48 (.51)	.06 (.08)	-.10 (-.16)	.27
Using technology increases my proficiency in mathematics.	.51 (.53)	-.05 (-.03)	-.15 (-.24)	.31
Using technology stimulates my interest in mathematics.	.00 (.06)	.84 (.87)	.10 (.28)	.76
Technology-supported mathematics education helps me to learn mathematics better.	.10 (.15)	.78 (.83)	.15 (.31)	.71
I like mathematics that challenges me.	-.06 (.02)	.81 (.80)	-.03 (.16)	.64
Using technology for learning mathematics can be a little scary.	.07 (.15)	.46 (.42)	-.19 (-.11)	.22
If I use technology in mathematics, I will not learn as well.	-.00 (.06)	.70 (.69)	-.02 (.13)	.48
Using technology gets in the way of learning mathematics.	-.12 (-.05)	.52 (.47)	-.17 (-.03)	.26
I think I will do better in mathematics courses if interactive learning activities are used.	-.04 (-.18)	-.01(.18)	.88 (.88)	.78
I wish I had more opportunities to engage in collaborative learning activities in class.	-.04 (.16)	-.14 (-.00)	.64 (.61)	.40
I would be happy if my learning process were evaluated in a prompt and continuous manner throughout the mathematics course.	-.03 (-.10)	.02 (.12)	.46 (.47)	.22

Note: Factor loadings < .4 are suppressed. 1 = attitudes towards mathematics 2 = attitudes towards technology-supported mathematics 3 = beliefs about learning mathematics.

a. Component correlations were as follows: $r_{12} = .09$, $r_{13} = -.16$, and $r_{23} = .22$

b. Pattern coefficients are followed by structure coefficients in parentheses.

Motivation to Learn Mathematics Subscale

The factorability of six motivation to learn mathematics items was reexamined. The Kaiser Criteria of eigenvalues and analysis of the scree plot showed that six items were grouped under two latent factors. The initial eigenvalues suggested that the first factor explained 26% of the variance, and the second factor explained 7% of the variance.

As a result, two-factor solution with $\chi^2(4, N = 121) = 1.032, p > .05$ that explained 33% of the variance was selected based on the eigenvalues and natural bends on the scree-plot. The internal replication analysis for the PFL-RICM Motivation to Learn Mathematics (MLM) indicated that the same items were loaded under the same two latent factors in both analyses, and the equivalencies of item factor loading were at the desired level. The factor loading matrix of the replication analysis of PFL-RICM (MLM) subscale is presented in Table 6.

Table 6.
PFL-RICM MLM Subscale Replicability Analysis Item Stems, Components, Coefficients, and Communalities for Phase 2 (N = 121)

Item Stem	Factors ^{ab}		h^2
	1	2	
The methods used in mathematics education affect my motivation.	.67 (.78)	.21 (.57)	.51
I have to study harder than my classmates to understand mathematics concepts.	.72 (.64)	-.15 (.23)	.57
The mathematics I learn is more important to me than the grade I receive.	.52 (.49)	-.05 (.23)	.30
I like to perform better than other students on mathematics tests.	.00 (.30)	.56 (.56)	.32
I feel more motivated when I receive immediate feedback.	-.13 (.16)	.54 (.47)	.25
Earning a good mathematics grade is more important to me than understanding the concepts.	.17 (.31)	-.25 (-.34)	.26

Note: Factor loadings < .20 are suppressed. 1 = intrinsic motivation 2 = extrinsic motivation

a. Component correlation was $r_{12} = .53$,

b. Pattern coefficients are followed by structure coefficients in parentheses.

Learner Satisfaction Subscale

The factorability of 12 learner satisfaction items was reexamined. The Kaiser Criteria of eigenvalues and analysis of the scree plot showed that the 12 items were grouped under three latent factors. The initial eigenvalues suggested that the first factor explained 28% of the variance, the second factor explained 9% of the variance, and the third factor also explained 6% of the variance. As a result, a three-factor solution with $\chi^2(33, N = 121) = 28.685, p > .05$ that explained 43% of the variance was selected based on the eigenvalues and natural bends on the scree-plot. Internal replication analysis for the PFL-RICM learner satisfaction scale concluded that the same items were loaded under the same three latent factors in both analyses, and the equivalencies of item factor loading were at the desired level. However, the item “I am satisfied with the accessibility of course grades outside of class” needs to be watched, because this item failed to pass two stages of the replicability analyses. Thus, it is recommended to exclude this item from the scale in future implementations. The factor loading matrix of the replication analysis of the PFL-RICM LS subscale is presented in Table 7.

Internal Consistency Reliability Analysis

Cronbach’s Alpha internal consistency reliability coefficients were calculated for each subscale separately over the two datasets ($N_1=121$; $N_2=121$), and reported respectively. The results indicated that Cronbach’s Alpha internal consistency reliability coefficient of the attitudes toward mathematics (ATM) subscale which consisted of eight items were .92 and .90; the attitudes toward technology-supported mathematics (ATSM) subscale which consisted of 6 items were .85 and .83; the learner beliefs about learning mathematics (LBM) subscale which consisted of 3 items were .77 and .66; intrinsic motivation to learn mathematics (IMLM)

subscale that consisted of three items were .67 and .66; extrinsic motivation to learn mathematics (EMLM)

Table 7.
PFL-RICM LS Subscale Replicability Analysis Item Stems, Components, Coefficients, and Communalities for Phase 2 (N = 121)

Item Stem	Factors ^{ab}			<i>h</i> ²
	1	2	3	
I am satisfied with the methods used to deliver course content in mathematics courses.	.94 (.84)	-.17 (.27)	-.08 (.09)	.74
I am satisfied with the overall quality of teaching experiences in mathematics classrooms.	.70 (.73)	.06 (.39)	-.02 (.13)	.53
Mathematics instruction needs to be improved.	.81 (.84)	.04 (.43)	.06 (.24)	.72
I am satisfied with my mathematics content proficiency (knowledge).	.68 (.72)	.09 (.41)	-.00 (.15)	.52
The mathematics instruction I have had so far causes me to question my Mathematics ability.	.47 (.49)	.04 (.26)	-.01 (.09)	.24
I am satisfied with the opportunities I have to participate and share my ideas during class activities.	-.03 (.25)	.63 (.61)	-.10 (-.03)	.38
I am satisfied with the accessibility of course materials outside of class.	.01 (.33)	.68 (.69)	.00 (.08)	.47
I am satisfied with the accessibility of course grades outside of class.	-.10 (.04)	.19 (.17)	.24 (.25)	.09
I am satisfied with the interactive group activities in mathematics classrooms.	.01 (.24)	.55 (.54)	-.11 (-.04)	.30
I am satisfied with the overall quality of immediate feedback opportunities in mathematics.	.16 (.46)	.52 (.63)	.27 (.37)	.50
Greater use of learning technologies in the mathematics classroom might increase my overall satisfaction with mathematics courses.	-.11 (.02)	-.08 (-.03)	.79 (.76)	.61
I am satisfied with the overall quality of my formal mathematics experiences.	.12 (.18)	-.12 (.00)	.60 (.60)	.38

Note: Factor loadings < .4 are suppressed. 1 = satisfaction from mathematics instruction, 2 = satisfaction from course redesign efforts, 3 = overall satisfaction from the mathematics learning experiences. Italicized coefficients are of those items retained for that component.

a. Component correlations were as follows: $r_{12} = .47$, $r_{13} = .20$, and $r_{23} = .12$

b. Pattern coefficients are followed by structure coefficients in parentheses.

subscale that consisted of three items were .50 and .42; satisfaction from mathematics instruction (SMI) subscale which consisted of 5 items were .82 and .84; satisfaction from redesigned mathematics learning experiences (STSL) subscale which consisted of 5 items were .76 and .64; and overall satisfaction from mathematics learning experiences (OSMLE) subscale which consisted of 2 items were .77 and .64.

Conclusion

The PFL-RICM scale was developed to measure students' attitudes toward mathematics, motivation to learn mathematics, and satisfaction from the instructional practices in redesigned college level mathematics courses. The scale was built on the underlying instructional dynamics of course redesign efforts in college level introductory mathematics classrooms. Specifically, the instructional practices offered by the Emporium model guided the item development process. The scale was developed as 74 items with 5 subscales, but only subscales developed for attitude toward mathematics, motivation to learn mathematics, and satisfaction from the instructional practices were examined in the scope of this paper. Two-stages of EFA analyses were conducted to analyze the internal structure validity and the internal replicability of the PFL-RICM scale. In the first step, initial EFAs were repeated multiple times to exclude items that were either cross-loaded under more than one factor, or their factor loadings were not at or above the cut-off values stepwise. As a result of initial EFA analyses, attitudes toward mathematics subscale was reduced from 22 to 17 items, and a three-factor structure was retained; the motivation to learn mathematics subscale was reduced from 10 to 6 items, and the two-factor structure was retained; and the learner satisfaction from mathematics instruction subscale was reduced from 17 to 12 items, and its three-factor structure was retained. Multicollinearity was an issue for the attitudes

toward mathematics subscale, and this was addressed by excluding the highly correlated three items from the subscale.

The final form of the PFL-RICM scale consists of 38 items which include one descriptive item, two random responding control items, and 35 likert items that were loaded under eight factors. Stage two EFA analyses were conducted for internal replicability analysis as suggested by Osborne (2014). Two criteria: loading of the same items under the same factors, and the difference between item factor loadings, were considered to decide whether replicability analyses were successful. Thirty-three items satisfied the two criteria. “Using technology for learning mathematics can be a little scary” had a slightly higher difference (.24) between item factor loadings in initial and replicability EFAs, and the item “I am satisfied with the accessibility of course grades outside of class” failed to meet the two criteria. The latter might be excluded from the PFL-RICM scale because of low item factor loadings, the notable difference between item factor loadings in the primary EFA analysis and the replicability analysis, and loading under different factor. However, both items were retained in the scale when instructional dynamics of the Emporium model in course redesign were considered, but it is highly recommended to watch for these items in future implementations.

Cronbach’s alpha internal consistency reliability coefficients were calculated for each subscale over two datasets. There are no designated cut-off values for a moderate or good reliability coefficient, but $\alpha=.70$ is accepted as adequate, whereas $\alpha=.80$ and above is good (Nunnally & Bernstein, 1994; Osborne, 2008; 2014). Osborne also reported that the average reliability is $\alpha=.80$ with standard error of .10 in a survey in Educational Psychology literature from 1998-1999. Reliability coefficients of attitudes toward mathematics subscales and learner

satisfaction subscales were considered as good although reliability coefficients of motivation to learn mathematics subscales were not at the desired level.

In conclusion, the PFL-RICM scale addresses the need for a new instrument to evaluate psychosocial factors of learning in college-level mathematics education literature. The PFL-RICM scale distinguishes itself from previously developed instruments, because it combines traditional statements of psychosocial factors of learning with new stems that focus on new trends in college level mathematics education, the course redesign. Two strengths of the PFL-RICM scale are (a) being built on the underlying dynamics of course redesign models, and (b) taking the possible impacts of technology use on psychosocial factors of learning in college level mathematics education into consideration. The scale can be used as a reliable and valid data collection instrument in redesigned college-level introductory mathematics courses which use the Emporium model. However, the scale can also be adapted for other course redesign models which show similarities with the Emporium model in terms of technology integration and other pedagogical practices. Finally, the PFL-RICM scale has potential to be implemented in the K-12 mathematics education context in which technology integration is a necessary practice in regular mathematics classrooms, and in which pedagogical practices have been changing from a teacher-centered approach to a student-centered constructivist approach for more than a decade. The final version of the PFL-RICM scale is provided in Appendix A.

CHAPTER 4

IMPACTS OF THE MATH EMPORIUM DELIVERY MODEL ON PSYCHOSOCIAL
FACTORS OF LEARNING IN COLLEGE ALGEBRA

Abstract

Changes in psychosocial factors of learning were examined, and students' attitudes toward mathematics, motivation to learn mathematics, and satisfaction from the instructional design were compared in both forms of college algebra: traditionally-taught and redesigned using the Math Emporium model. The results of the study revealed that attitudes toward technology-supported mathematics, beliefs about learning mathematics, and overall attitudes toward mathematics changed significantly in both educational settings, whereas attitudes toward mathematics, extrinsic motivation to learn mathematics, and learner satisfaction from instructional design, from technology-supported mathematics, and from mathematics instruction changed significantly in the redesigned sessions throughout the semester. Only attitudes toward mathematics and attitudes toward technology-supported mathematics were significantly different between the traditionally-taught and the redesigned college algebra sessions.

Introduction

College algebra has been placed at the center of the reform movement in undergraduate mathematics for more than a decade. Small (2006) called for an urgent transformation for college algebra and similar gateway courses which are not functioning properly. Nationwide, the success rate in college algebra courses is around 40% (Burn, 2012; Haver et al., 2007; Small, 2006; Thompson & McCann, 2010). According to Aichele, Francisco, Utley, and Wescoatt (2011) “...less-than-desirable student success rates; high student drop rates; variability among sections and semesters with respect to grade assigned and content expectations; and controlling cost of course delivery” (p. 13) are some of the underlying problems that need to be resolved in college level introductory mathematics courses for better student learning outcomes. Specifically, high failure and withdrawal rates can be triggered by various causal factors in college algebra. For example, Gordon (2008) summarized that not being able to keep up with changing learner demographics, dramatic improvements of instructional technology in mathematics education, and changing needs and expectations of learners are the main reasons for failure in college algebra courses.

Course redesign efforts have shown a continuous and positive impact on college algebra and on similar introductory level mathematics courses which suffered from the aforementioned problems for nearly two decades (see Twigg, 2005). The NCAT, which was established in 1999 with a support from Pew Charitable Trusts, provides six different course redesign models that share the same goals: improving academic achievement and reducing the cost of instruction (NCAT, 2015g; Twigg, 2003c). Institutional reports indicate that, among those, the Emporium model yields the best student learning outcomes, and cost savings in the introductory level

mathematics courses that include college algebra. Cost saving is not in the scope of this paper; how the Emporium model affects psychosocial factors of learning is the primary concern.

The research institution being studied had two main goals to achieve at the end of the college algebra (Math 110) course redesign: to increase retention by lowering the DFW rate which was approximately 30% over the previous two semesters, and to reduce the cost of instruction (MSCRI, 2011). The Emporium college algebra was piloted at the research institution in the Spring 2012 semester, and fully-implemented in the Fall 2012 semester after revisions were made based on the lessons learned from the pilot implementation. College algebra traditionally was a three-credit course taught as three 50-minute lectures by graduate teaching assistants (GTAs) or adjunct instructors in a traditional/lecture-based format (MSCRI). This instructional design is fairly typical for college level introductory mathematics courses, and full time faculty involvement is generally limited. For example, selecting textbooks and creating common final exams were two tasks that full-time faculty actively participated in for college algebra instruction at the research institution (MSCRI).

The Emporium, on the other hand, changes the roles of educators, involves instructors who have new responsibilities, and increases the involvement of at least one full-time faculty in instructional design and the teaching process. Based on the Emporium model, the research institution replaced all 50-minute lectures with two 75-minute interactive learning lab (ILL) sessions and one 50-minute lecture (MSCRI, 2011). The 50-minute class meetings in which key concepts and future tasks were reviewed were taught by a faculty member who was the primary coordinator/instructor of the course (MSCRI). In the ILL sessions, students worked collaboratively through an online classroom management system under the supervision of GTAs or adjunct instructors and undergraduate teaching assistants (UTAs) who provided on-demand

help and immediate feedback (MSCRI). Such an interactive learning environment supported by extensive instructional and learning technology has been shown to provide flexibility and convenience that allows students to learn mathematics by doing.

Instructional and learning technology integration is an essential part of the Emporium model. However, attributing better academic achievement solely on ILT integration could possibly be misleading. More attention should be paid to the affective variables of learning such as attitudes toward subject matter, motivation to learn, and satisfaction from the instructional design and practices that directly or indirectly influence academic achievement and retention in this educational context. Not only cognitive variables, but also affective factors influence academic achievement (Tocci & Engelhard, 1991, as cited in Papanastasiou, 2000). The psychosocial factors of learning are most likely to be affected by the course redesign efforts which offer flexibility and convenience, and support interaction and collaboration in college algebra. Thus, the main purpose of this research paper is to investigate whether instructional practices in course redesign and in traditional (lecture-dominated) college algebra influence the psychosocial factors of learning. The following research questions were investigated: (a) Do attitudes toward mathematics, motivation to learn mathematics, and satisfaction from the mathematics learning experiences change significantly during redesigned and traditional college algebra sessions? (b) Is there a statistically significant difference between the psychosocial factors of learning in both forms of college algebra after controlling for pre-existing scores? The following nine hypotheses were tested through paired samples t-tests, and multiple regression.

H₀A: There are no statistically significant changes in students' attitudes toward mathematics ($p=.923$), attitudes toward technology-supported mathematics ($p=.038$), beliefs about learning mathematics ($p=.040$), and overall attitudes

toward mathematics ($p=.011$) within traditionally-taught college algebra sessions over the course of a semester.

H₀B: There are no statistically significant changes in students' intrinsic motivation ($p=.514$) to learn mathematics, extrinsic motivation ($p=.267$) to learn mathematics and overall motivation ($p=.818$) to learn mathematics within traditionally-taught college algebra sessions over the course of a semester.

H₀C: There are no statistically significant changes in students' satisfaction from mathematics instruction ($p=.239$), satisfaction from technology-supported mathematics education ($p=.290$), satisfaction from instructional design ($p=.124$), and overall learner satisfaction ($p=.466$) from the college algebra within traditionally-taught college algebra sessions over the course of a semester.

H₀D: There are no statistically significant changes in students' attitudes toward mathematics ($p=.000$), attitudes toward technology-supported mathematics ($p=.004$), beliefs about learning mathematics ($p=.728$), and overall attitudes toward mathematics ($p=.000$) within redesigned college algebra sessions using the Emporium model over the course of a semester.

H₀E: There are no statistically significant changes in students' intrinsic motivation ($p=.749$) to learn mathematics, extrinsic motivation ($p=.044$) to learn mathematics and overall motivation ($p=.228$) to learn mathematics within redesigned college algebra sessions using the Emporium model over the course of a semester.

H₀F: There are no statistically significant changes in students' satisfaction from mathematics instruction ($p=.622$), satisfaction from technology-supported

mathematics education ($p=.000$), satisfaction from instructional design ($p=.000$), and overall learner satisfaction ($p=.000$) from the college algebra within redesigned college algebra sessions using the Emporium model over the course of a semester.

H₀G: There is no statistically significant difference between traditionally-taught and redesigned college algebra sessions regarding students' attitudes toward mathematics ($p=.015$), attitudes towards technology-supported mathematics ($p=.008$), beliefs about learning mathematics ($p=.083$), and overall attitudes towards mathematics ($p=.405$) after controlling for pre-determined attitude, motivation, and satisfaction scores.

H₀H: There is no statistically significant difference between traditionally-taught and redesigned college algebra sessions regarding students' intrinsic motivation ($p=.636$) to learn mathematics, extrinsic motivation ($p=.852$) to learn mathematics, and overall motivation ($p=.230$) to learn mathematics after controlling for pre-determined attitude, motivation, and satisfaction scores.

H₀I: There is no statistically significant difference between traditionally-taught and redesigned college algebra sessions regarding students' satisfaction from mathematics instruction ($p=.632$), satisfaction from technology-supported mathematics education ($p=.601$), satisfaction from instructional design ($p=.087$), and overall learner satisfaction ($p=.138$) from the college algebra after controlling for pre-determined attitude, motivation, and satisfaction scores.

Literature Review

Everyone can learn and do mathematics, but why do college level mathematics courses suffer from high failure and withdrawal rates? Perhaps, the question that needs to be asked should be whether the students in these courses want to learn or not. The problem in mathematics education is not that students cannot learn mathematics, it is that they do not want to learn (Csikszentmihalyi & Wong, 2014). Although numerous reasons can be listed by one who does not want to learn mathematics, the majority are affective factors that can be grouped under four general categories: attitudinal approaches; beliefs in learning mathematics; motivational support; and satisfaction from previous mathematics learning experiences. Papanastasiou (2000) summarized that there is a positive correlation between the students' attitudes toward mathematics and academic achievement in mathematics, and this relationship is dual-sided which means students who perform better in mathematics tend to have positive attitudes toward mathematics. In a comparative study, Papanastasiou concluded that teaching and reinforcement are two factors having the strongest direct impact on attitudes toward mathematics. The Emporium model supports both of these factors through a student-centered teaching approach and on-demand help with immediate feedback.

House and Telese (2008) examined the Trends in International Mathematics and Science (TIMMS) 2003 results in Japan and in the United States, and concluded that students who indicated positive beliefs in their mathematics ability tended to perform better in mathematics. According to House and Telese, algebra achievement is significantly related to students' mathematics beliefs and classroom instructional practices. Middleton and Spanias (1999) stated that the most important finding across theoretical orientations was that "achievement motivation in mathematics, though stable, can be affected through careful instructional design" (p. 82).

Biner, Barone, Welsh and Dean (1997) reported that overall student satisfaction, learning satisfaction with interaction with instructors, and satisfaction from the technology integration in instructional design were highly associated with academic achievement. To summarize, affective factors of learning are influenced by instructional design and teaching practices in various instructional settings that include traditional and online teaching practices at different grade levels, and college algebra is not an exception.

Students' attitudes which are not inherited, but learned, can change during the course of the semester (Sundre, Barry, Gynnild, & Ostgard, 2012) because attitudes toward a specific subject matter can be affected by malleable factors such as heavy use of technology, instructional design and teaching practices. Despite Sundre et al., McLeod (1992) emphasized the stability of beliefs and attitudes in mathematics education, saying beliefs are cognitive in nature, and need a long period of time to develop. Therefore, four months might not be enough to observe significant changes in the affective domain of learners in mathematics education. In mathematics education, students' attitudes and beliefs about learning mathematics is considered as an important factor for their academic achievement (Ernest, 1991 as cited in Parsons, 2004). Pierce, Stacey and Barkatsas (2007) emphasized that "[a]ttitudes can be affected by recent experience, a series of experiences promoting positive or negative attitude can indeed contribute to the development of more persistent attitudes and even beliefs which are deeply held and strongly influence future behaviour" (p.286). Haladyna, Shaughnessy, and Shaughnessy (1983) summarized that overall quality of the teaching practices and social-psychological context of the classroom impact learners' attitudes toward mathematics. As an important part of instructional practices in today's classrooms, technology integration and dramatic changes in course structure also have potential to impact learners' attitudes about subject matter at all grade levels. In

mathematics education, for example, as instructional practices become more relevant, meaningful, and satisfactory, attitudes toward mathematics change positively, and learners' motivation to learn increases through integration of technology such as computers and calculators (Rochowicz, 1996).

Motivation, which correlates with various learning outcomes such as curiosity, persistence, learning, and performance, is one of the most important psychological concepts in educational contexts (Vallerand, Pelletier, Blais, Briere, Senecal, & Vallieres, 1992). Motivations are defined as reasons that give energy and direction to behaviors in a given manner and in a given context (Middleton & Spanias, 1999; Waugh, 2002). Middleton and Spanias reported that "motivations toward mathematics are developed early, are highly stable over time, and are influenced greatly by teacher actions and attitudes" (p. 80). However, Cardetti and McKenna (2011) stated that "it is natural to assume that some of the same motivations carry over from high school to the university setting" (p. 353). In educational contexts, motivational resources are grouped under two general categories: extrinsic and intrinsic. According to Knowles and Kerkman (2007), recognition and rewards are two general criteria for extrinsically motivated learners, whereas intrinsic motivation can be defined as an internal desire to learn a specific concept. Rugutt and Chemosit (2009) examined determinants of motivation to learn at the college level, and concluded that critical thinking skills, student-student and student-faculty interactions are statistically significant predictors of student motivation. Heafner (2004) examined the impact of technology use on learners' motivation to learn in social studies, and concluded that technology integration modifies the nature of given tasks, increases self-efficacy, self-confidence and self-worth; empowers student engagement; and improves students interest and enjoyment. Motivation is not only a dependent variable that is affected by various

educational decisions and practices, but also an independent variable that can possibly impact student learning outcomes. For example, Klein, Noe and Wang (2006) concluded that course outcomes that include learner satisfaction and academic achievement are affected by students' motivation to learn.

Learner satisfaction is one of the main concerns especially in distance education and online learning settings. Although there are various predictors of learner satisfaction in an educational setting regardless of delivery mode, in a mixed-method study with a sample size of 19, Gunawardena, Linder-VanBerschot, LaPointe, and Rao (2010) analyzed online self-efficacy, course design, learner-learner interaction and learner-instructor interaction as predictors of learner satisfaction in online courses. They concluded that these four variables explained 88% of the variance in learner satisfaction, and as a result of qualitative analysis, reported teaching practices, effective course design and delivery, the instructor, organizational support, socio-cultural components, and learning medium were other predictors of learning satisfaction. Comparative studies of learner satisfaction in face-to-face and in online learning yield inconsistent results. For example, Roach and Lemasters (2006) compared learner satisfaction in online learning and in traditional face-to face courses, and reported that students who enrolled in online courses were more satisfied than their peers who took the courses face-to-face. In a meta-analysis, Allen, Bourhis, Burrell and Marby (2002) compared student satisfaction in distance education and in traditional settings. According to Allen et al., students enrolled in traditional lecture-based courses reported a slightly higher level of satisfaction than their peers who enrolled in distance education sessions. In a comparative study, Kearns, Shoaf, and Summey (2004) reported that students enrolled in courses that were taught online were less satisfied than students who enrolled in a web-based course, but performed better than their peers who took the courses

face-to-face. As a result of comparing student satisfaction, learning effectiveness, and faculty satisfaction in face-to-face, blended and online modes of instruction, Larson and Sung (2009) reported that online and blended modes of instruction are preferred to face-to-face instruction. The Emporium model makes heavy use of instructional and learning technologies in its course redesign for convenience, flexibility, peer interaction, learner-faculty interaction, and better course design. All those elements of the Emporium model show similarities with the web-based learning practices described above. Thus, it is natural to expect that similar factors will impact student satisfaction when the instructional dynamics of the Emporium model are considered.

Attitudes toward mathematics, and motivation to learn mathematics have been studied in K-12 mathematics education, whereas research on satisfaction from the instructional design has been widely conducted in online and distance learning environments. The research on psychosocial factors of learning at the college level is limited, specifically in mathematics classrooms. Only a few institutions that redesigned introductory level courses paid attention to psychosocial factors of learning; these were typically not college level mathematics courses. The University of Massachusetts –Amherst, for example, redesigned the introductory biology courses in the fall 2000 semester, and examined student attitudes toward science. Although positive changes in attitude scores were noted, such a small change was attributed to the timing of the survey deployment and composition of the population (NCAT, 2015d). Likewise, improved attitudes toward subject matter was reported in Developmental English at Glendale Community College, in Physics at North Carolina State University, and in introductory engineering courses at University of Texas. The Tallahassee Community College (NCAT, 2015c) examined learner and instructor motivation in a redesigned College Composition course, and indicated that all groups reported increased motivation to some degree by noting that many students dropped out

before completing the post-tests. The North Carolina State University also reported widespread student satisfaction in introductory physics courses (NCAT, 2015f). The University of Central Florida (NCAT, 2015b) reported increased learner satisfaction especially when student-student interaction was facilitated in a redesigned American National Governments course. The University of Alabama (NCAT, 2015a) reported that learner satisfaction in redesigned intermediate algebra courses in 2001-2002 were the highest of the past four years.

The affective domain, and psychosocial factors of learning have significant importance in learning mathematics at all grade levels. Although extensive research is available in K-12 mathematics education and online education literature, research on psychosocial factors of learning in redesigned college-level introductory mathematics courses is almost non-existent. Accessible research results are limited to course redesign reports submitted by participating institutions, and the results cannot necessarily be generalized to the redesigned mathematics education context. This research paper purposes to fill this gap.

Method

Sampling

Convenience sampling was used, and college level students who were older than 18 years of age, and enrolled in traditional or redesigned college algebra sessions at a Midwestern research university were invited to voluntarily participate in this study. Total number of participants was 687, but the sample size reduced to 229 because of incomplete data, outliers, and students who completed the pretest, but not the posttest or vice versa. Briefly, 28 participants were excluded because of incomplete pretests, whereas 272 were excluded because of incomplete posttests. This was not unexpected because dropout rates are often high in college algebra classes. In total, 59 participants were excluded because of respondent control items

which were embedded into the survey to check how much attention was paid to the survey items. Ninety-nine cases were excluded because of outliers, blank responses, and missing data. Students who enrolled in the college algebra course, completed the questionnaire, but withdrew from the course, and subsequently reenrolled in the course in upcoming semesters were excluded from the study, so only participants who completed both pretest and posttest questionnaire were retained. Respectively, 117 and 112 participants were recruited from traditional college algebra sessions and from redesigned college algebra sessions. As a compensation, 5 points were added to all participants' final exam scores, and students who are not eligible to participate were given a mathematics worksheet, and received 5 extra points upon completion. Student demographics such as age, gender, race etc. were not sought, but intended majors of participants were requested. Fifty-eight different fields were reported ranging from architecture to music education. This, too, was also expected since college algebra is a required course for almost all disciplines, and such requirements give rise to high enrollment rates in college algebra.

Instrumentation

The psychosocial factors of learning in redesigned introductory mathematics (PFL-RIM) survey developed by the researcher, was used to collect data on students' attitudes toward mathematics, motivation to learn mathematics, and satisfaction from the instructional practices and design. Explanatory and internal replicability factor analyses on the instrument suggested that the PFL-RIM scale is a reliable and valid data collection tool (Demiroz, in progress). The overall reliability coefficient of the 38-item PFL-RIM scale was .84 (Demiroz, in progress). The Cronbach's Alpha reliability coefficient was .87 for the current dataset. The instrument includes one descriptive item, two random response control items, and 35 likert items. The scale consists of three subscales: attitudes toward mathematics ($\alpha=.82$), motivation to learn mathematics

($\alpha=.65$) and satisfaction from the instructional design and practices ($\alpha=.80$). Attitudes toward mathematics, measured through 17 items, consists of three factors: attitudes toward mathematics, attitudes toward technology-supported mathematics, and learner beliefs in learning mathematics; Motivation to learn mathematics, measured through six items, consists of two factors: extrinsic and intrinsic motivation; Satisfaction from the instructional design and practices, measured with 12 items, consists of three factors which are satisfaction from mathematics instruction, satisfaction from course redesign efforts, and overall satisfaction from the mathematics learning experiences (Demiroz, in progress).

Procedure

This quasi-experimental research study uses pre-test/posttest, control group design. The Emporium model course redesign was considered treatment, and students who enrolled in the redesigned sections of college algebra were designated the treatment group, whereas students enrolled in the traditional college algebra sections were included in the research as the control group. Participants in the treatment group were taught college algebra in the redesigned format. They were required to attend Interactive Learning Lab (ILL), which was fully equipped with instructional and learning technologies, sessions a total of 150 minutes, and a 50-minute in-class session each week. As a part of the treatment, interaction between peers, and between faculty and students was encouraged and participants were exposed to student-centered instruction with immediate feedback and on-demand help. The treatment made heavy use of instructional and learning technologies such as online textbooks and classroom management systems (MSCRI, 2011). Participants in the control group received college algebra instruction in a traditional (50-minute lecture-based) format three times a week. Participants in the control group were passive listeners, and the instructors lectured in traditional sessions of college algebra. Participants'

assignments into treatment and control groups were not randomized, but self-selective. In other words, students enrolled in redesigned and traditional sections of the college algebra at the research institution at their discretion and the researcher was not able to manipulate the process. However, it is possible that students selected a section for a variety of reasons including time of the day, schedule conflicts, total class time required and open (or closed) sections. The instrument developed by the researcher was administered twice: at the beginning of the semester as a pretest, and at the end of the semester as a posttest in both traditional and redesigned sections of college algebra.

Data Analysis

After preliminary screening and testing for assumptions, two sets of data analyses were completed to test the hypotheses stated above. Within-group pretest-posttest comparisons were made through paired-samples t-tests, whereas multiple regression analyses were performed for testing the statistical difference between treatment (redesign) and control (traditional) groups. Preliminary analyses indicated that results of Kolmogorov-Smirnov and Shapiro-Wilk tests of normality are statistically significant for some of the variables, but not for all. However, Brown (2011) stated that skewness and kurtosis values between +2 and -2 are desirable to accept that the data are normally distributed. Curran, West, and Finch (1996) recommended that univariate values of skewness and kurtosis indicate a non-normal distribution when they approach 2 and 7 respectively. When histograms, Q-Q plots, skewness (ranging between +1,-1) and kurtosis (ranging between +2,-2) values were considered, data were determined to be normally distributed for further analyses. The first set of between-group comparisons was made by including treatment by covariate interaction to test homogeneity of regression and no treatment-by-covariate interaction assumptions. None of the interaction terms was statistically significant, so

these two assumptions were not violated (Warner, 2014). Therefore, multiple regression analyses were repeated without including a treatment-by-covariate interaction term. The posttest scores were normally distributed, the pretest scores were not statistically significantly different for the control (traditional) and treatment (redesigned) groups, and scatterplots indicated a linear relation and no bivariate outliers. No data transformations were applied, but five cases were randomly excluded from the control group to ensure an equal number of cases in both groups for the multiple regression analyses. All 224 cases were included in the multiple regression analysis.

Results

Within Group Comparisons.

Possible changes in dependent variables were analyzed through paired-samples t-test analyses. The following section reports statistical analyses for one of the research questions: Do dependent variables significantly change within control (traditionally-taught college algebra) and within treatment (redesigned-college algebra) groups during the four month treatment? Twenty-two paired-sample comparisons were made for the eight dependent variables, and overall attitudes, motivation, and satisfaction variables. The results of the paired-samples t-test analyses are shown in Table 2 and Table 3.

Attitudes

A paired-samples t-test was conducted to analyze whether learners' attitudes toward mathematics, attitudes toward technology-supported mathematics, beliefs about learning mathematics, and overall attitudes toward mathematics changed throughout the traditionally-taught and redesigned college algebra courses during the 4 month period. The results of the paired-samples t-test indicated that the mean scores of attitudes toward technology-supported mathematics (pretest: $M=3.04$, $SD=.69$; posttest: $M=2.87$, $SD=.41$), beliefs about learning

mathematics (pretest: $M=3.65$, $SD=.66$; posttest: $M=3.51$, $SD=.75$), and overall attitudes toward mathematics (pretest: $M=3.17$, $SD=.41$; posttest: $M=3.07$, $SD=.38$) changed negatively.

Table 8.
Paired Samples Statistics

<i>Pairs</i>	<i>Control Group</i>				<i>Treatment Group</i>			
	<i>Mean^a</i>	<i>SD</i>	<i>Mean^b</i>	<i>SD</i>	<i>Mean^a</i>	<i>SD</i>	<i>Mean^b</i>	<i>SD</i>
Attitudes toward mathematics	2.81	.86	2.82	.47	3.12	.93	.79	.58
Attitudes toward technology-supported mathematics	3.04	.69	2.87	.41	3.24	.77	2.98	.44
Beliefs about learning mathematics	3.65	.65	3.51	.75	3.78	.65	3.75	.85
Intrinsic motivation to learn mathematics	2.88	.70	2.92	.76	2.85	.61	2.87	.67
Extrinsic motivation to learn mathematics	3.65	.62	3.59	.64	3.79	.56	3.67	.57
Satisfaction from mathematics instruction	3.02	.78	3.10	.34	3.13	.80	3.09	.49
Satisfaction from tech-supported mathematics	3.34	.56	3.26	.77	3.62	.66	3.35	.71
Satisfaction from instructional design	3.19	.68	3.07	.78	3.41	.71	3.00	.88
Overall attitudes toward mathematics	3.17	.41	3.07	.38	3.38	.45	3.17	.41
Overall motivation to learn mathematics	3.26	.54	3.25	.58	3.32	.48	3.27	.53
Overall learner satisfaction	3.18	.55	3.15	.50	3.39	.60	3.15	.56

a :Pretest Scores; b: Posttest Scores

The mean differences were statistically significant at the .05 level of significance in the traditionally-taught college algebra sessions. Also, one of the factors of the instrument, the mean score of attitudes toward mathematics (pretest: $M=2.81$, $SD=.86$; posttest: $M=2.82$, $SD=.47$)

changed positively, but the mean difference is not statistically significant at .05 level of significance.

The results of the paired-samples t-test for the treatment group showed that the mean scores of attitudes toward mathematics (pretest: $M=3.12$, $SD=.93$; posttest: $M=2.79$, $SD=.58$), attitudes toward technology-supported mathematics (pretest: $M=3.24$, $SD=.77$; posttest: $M=2.98$, $SD=.44$), and overall attitudes toward mathematics (pretest: $M=3.38$, $SD=.45$; posttest: $M=3.17$, $SD=.41$) changed negatively, and the mean differences were statistically significant at the .05 level of significance. In addition, the mean score of beliefs about learning mathematics changed negatively, but the mean difference is not statistically significant at .05 level of significance.

Motivation

A paired-samples t-test was conducted to analyze whether learners' intrinsic motivation to learn mathematics, extrinsic motivation to learn mathematics, and overall motivation to learn mathematics changed throughout the traditionally-taught college algebra and redesigned college algebra courses during the 4 month period. The results of the paired-samples t-tests indicated that the mean scores of intrinsic motivation to learn mathematics (pretest: $M=2.88$, $SD=.70$; posttest: $M=2.92$, $SD=.76$) changed positively, whereas extrinsic motivation to learn mathematics (pretest: $M=3.65$, $SD=.61$; posttest: $M=3.59$, $SD=.64$), and overall motivation to learn mathematics (pretest: $M=3.26$, $SD=.54$; posttest: $M=3.25$, $SD=.58$) changed negatively in the control group - traditionally-taught college algebra. However, none of those mean differences is statistically significant at the .05 level of significance.

The paired-samples t-test for the treatment group indicated similar results to the control group. The mean scores of intrinsic motivation to learn mathematics (pretest: $M=2.85$, $SD=.61$; posttest: $M=2.87$, $SD=.67$) changed positively whereas extrinsic motivation to learn mathematics

(pretest: $M=3.79$, $SD=.56$; posttest: $M=3.67$, $SD=.57$), and overall motivation to learn mathematics (pretest: $M=3.32$, $SD=.48$; posttest: $M=3.27$, $SD=.53$) changed negatively in the redesigned college algebra. The mean difference for extrinsic motivation was statistically significant at the .05 level of significance although the mean differences of intrinsic motivation and overall motivation to learn mathematics were not statistically significant at the .05 level of significance.

Learner Satisfaction

A paired-samples t-test was conducted to analyze whether learners' satisfaction from mathematics instruction, technology-supported mathematics, instructional design, and overall satisfaction from college algebra changed throughout the traditionally-taught and redesigned college algebra sessions during the 4 month period. The results of the paired-samples t-test indicated that the mean scores of learner satisfaction from technology-supported mathematics ($M=3.34$, $SD=.56$; posttest $M=3.26$, $SD=.77$), learner satisfaction from instructional design (pretest: $M=3.19$, $SD=.68$; posttest: $M=3.07$, $SD=.78$), and overall learner satisfaction from college algebra (pretest $M=3.18$, $SD=.55$; posttest $M=3.15$, $SD=.50$) changed negatively, whereas the mean score of learner satisfaction from mathematics instruction changed positively (pretest: $M=3.01$, $SD=.78$; posttest: $M=3.10$, $SD=.34$). None of the mean differences was statistically significant at the .05 level of significance.

The results of the paired-samples t-test for the treatment group indicated that the mean scores of learner satisfaction from mathematics instruction (pretest: $M=3.13$, $SD=.80$; posttest: $M=3.09$, $SD=.49$), learner satisfaction from technology-supported mathematics

Table 9.

Paired-Samples T-Test Comparisons in Control Group.

<i>Control Group (Traditionally-taught college algebra)</i>						
<i>Scale</i>	<i>Mean^a</i>	<i>Mean^b</i>	<i>Δ Mean</i>	<i>SD</i>	<i>t value</i>	<i>Sig.</i>
Attitudes toward mathematics	2.81	2.82	-.006	.71	-.097	.923
Attitudes toward technology-supported mathematics	3.04	2.87	.17	.89	2.102	.038*
Beliefs about learning mathematics	3.65	3.51	.14	.73	2.080	.040*
Intrinsic motivation to learn mathematics	2.88	2.92	-.04	.66	-.654	.514
Extrinsic motivation to learn mathematics	3.65	3.59	.06	.58	1.116	.267
Satisfaction from mathematics instruction	3.02	3.10	.08	.75	-1.183	.239
Satisfaction from tech-supported mathematics	3.34	3.26	.07	.75	1.064	.290
Satisfaction from instructional design	3.19	3.07	.12	.83	1.551	.124
Overall attitudes toward mathematics	3.17	3.07	.10	.43	2.578	.011*
Overall motivation to learn mathematics	3.26	3.25	.01	.47	.230	.818
Overall learner satisfaction	3.18	3.15	.04	.55	.731	.466

* Indicates statistically significant mean differences ($p < .05$); a: Pretest Scores; b: Posttest Scores

(pretest: $M=3.62$, $SD=.66$; posttest: $M=3.35$, $SD=.71$), learner satisfaction from instructional design (pretest: $M=3.41$, $SD=.71$; posttest: $M=3.00$, $SD=.88$), and learner satisfaction from college algebra (pretest: ($M=3.39$, $SD=.60$; posttest: $M=3.15$, $SD=.56$) changed negatively. The mean differences of the latter three variables were statistically significant at the .05 level of significance, but the mean difference of learner satisfaction from mathematics instruction was not statistically significant at the .05 level of significance.

Between Group Comparisons

Multiple regression analyses were performed to assess whether there were statistically significant differences in dependent variables between traditionally-taught college algebra and

redesigned college algebra after controlling for pretest scores. The results of the multiple regression analyses are shown in Table 4.

Table 10.
Paired-Samples T-Test Comparisons in Treatment Group.

<i>Scale</i>	<i>Control Group (Traditionally-taught college algebra)</i>					
	<i>Mean^a</i>	<i>Mean^b</i>	<i>Δ Mean</i>	<i>SD</i>	<i>t value</i>	<i>Sig.</i>
Attitudes toward mathematics	3.12	2.79	.33	.69	5.035	.000*
Attitudes toward technology-supported mathematics	3.24	2.98	.26	.95	2.980	.004*
Beliefs about learning mathematics	3.78	3.75	.03	.81	.349	.728
Intrinsic motivation to learn mathematics	2.85	2.87	-.02	.59	-.320	.749
Extrinsic motivation to learn mathematics	3.79	3.67	.12	.60	2.037	.044*
Satisfaction from mathematics instruction	3.13	3.09	.04	.84	.494	.622
Satisfaction from tech-supported mathematics	3.62	3.35	.27	.73	3.918	.000*
Satisfaction from instructional design	3.41	3.00	.41	.88	4.979	.000*
Overall attitudes toward mathematics	3.38	3.17	.21	.49	4.513	.000*
Overall motivation to learn mathematics	3.32	3.08	.24	.43	1.212	.228
Overall learner satisfaction	3.39	3.15	.24	.56	4.580	.000*

* Indicates statistically significant mean differences ($p < .05$); a: Pretest Scores; b: Posttest Scores

Attitudes

The results of regression analysis for attitudes toward mathematics and attitudes toward technology-supported mathematics indicated that the overall regression equations were statistically significant for attitudes toward mathematics ($R = .62$, $R^2 = .38$, adjusted $R^2 = .37$, $F(2, 221) = 67.448$, $p < .001$) and attitudes toward technology-supported mathematics ($R = .26$, $R^2 = .07$, adjusted $R^2 = .06$, $F(2, 221) = 8.071$, $p < .001$) posttest scores. When controlling for the effect of pretest scores, the magnitude of the group difference in attitudes toward mathematics was $-.138$

and in attitudes toward technology supported mathematics was .148. The differences were statistically significant: $t(224) = -2.451, p=.015$ and $t(224) = 2.658, p=.008$ respectively. The results of regression analyses for students' beliefs about learning mathematics ($R = .47, R^2=.23$, adjusted $R^2=.22, F(2, 221) = 32.018, p<.001$), and overall attitudes toward mathematics ($R = .41, R^2=.17$, adjusted $R^2=.16, F(2, 221) = 21.817, p<.001$) indicated that the overall regression equations were also statistically significant for learners' beliefs and overall attitude posttest scores. The magnitude of the group difference in learner beliefs about learning mathematics was .168 and overall attitudes toward mathematics was .042. The differences were not statistically significant: $t(224) = 1.742, p=.083$ and $t(224) = .834, p=.405$ respectively. The traditional group had a mean attitude posttest score of 2.82 while the mean score for the redesign group was 2.79. The results suggested that the redesign efforts negatively impacted students' attitudes toward mathematics. On the other hand, the redesign efforts positively impacted students' attitudes toward technology-supported mathematics. Although the differences were not statistically significant, the mean scores of students' beliefs about learning mathematics, and overall attitudes toward mathematics were higher in the redesigned college algebra sessions.

Motivation

The results of regression analyses for intrinsic motivations ($R = .58, R^2=.34$, adjusted $R^2=.34, F(2, 221) = 57.637, p<.001$), extrinsic motivations ($R = .50, R^2=.25$, adjusted $R^2=.25, F(2, 221) = 37.340, p<.001$), and overall motivation of students ($R = .65, R^2=.43$, adjusted $R^2=.42, F(2, 221) = 82.186, p<.001$) to learn mathematics indicated that the overall regression equations were statistically significant for all three. When controlling for the effect of pretest scores, the magnitude of the group difference in intrinsic motivation to learn mathematics was -.037, but the difference was not statistically significant: $t(224) = -.474, p=.636$. Likewise, the magnitude of

the group difference in extrinsic motivation to learn mathematics was .013, and the difference was not statistically significant: $t(224) = .187, p = .852$ when controlling for the effect of pretest scores. Finally, the regression analysis results revealed that the magnitude of the group difference in overall motivation to learn mathematics was -.078, and the difference was not statistically significant: $t(224) = -1.205, p = .230$ when controlling for the effect of pretest scores. Although the group differences were not statistically significant, students enrolled in traditional college algebra sessions had higher intrinsic motivation and overall motivation to learn mathematics mean scores, whereas students enrolled in redesigned college algebra had higher extrinsic motivation to learn mathematics scores. However, it should be noted that students enrolled in redesigned college algebra sessions also had higher pretest scores of extrinsic motivation although the pretest scores did not statistically significantly differ between groups.

Learner Satisfaction

The results of regression analyses for satisfaction from mathematics instruction, satisfaction from technology-supported mathematics instruction, satisfaction from instructional design, and overall learner satisfaction from college algebra learning experiences indicated that the overall regression equations were statistically significant for satisfaction from mathematics instruction ($R = .23, R^2 = .05, \text{adjusted } R^2 = .04, F(2, 221) = 6.043, p < .005$), satisfaction from technology-supported mathematics instruction ($R = .42, R^2 = .17, \text{adjusted } R^2 = .17, F(2, 221) = 23.160, p < .001$), satisfaction from instructional design ($R = .39, R^2 = .150, \text{adjusted } R^2 = .14, F(2, 221) = 19.563, p < .001$), and overall learner satisfaction from college algebra learning experience ($R = .50, R^2 = .25, \text{adjusted } R^2 = .24, F(2, 221) = 36.292, p < .001$) posttest scores. When controlling for the effect of pretest scores, the magnitude of the group difference in satisfaction

from mathematics instruction was -.026, and the difference was not statistically significant: $t(224) = -.480, p=.632$.

Table 11.
Multiple Regression Analyses - Group Comparisons.

	Control vs. Treatment Groups ^{ab}									
	Mean Statistics			B Statistics		Regression Model Statistics				
	Mean ^a	Mean ^b	Δ Mean	t value	p value	B	F Value	df	p	Adj. R ²
Attitudes toward mathematics	2.82	2.79	.03	-2.451	.015*	-.138	67.448	2, 221	.000	.37
Attitudes toward technology-supported mathematics	2.85	2.98	-.13	2.658	.008*	.148	8.071	2, 221	.000	.06
Beliefs about learning mathematics	3.50	3.75	-.25	1.742	.083	.168	32.018	2, 221	.000	.22
Intrinsic motivation to learn mathematics	2.91	2.87	.04	-.474	.636	-.037	57.637	2, 221	.000	.34
Extrinsic motivation to learn mathematics	3.58	3.67	-.09	.187	.852	.013	37.340	2, 221	.000	.25
Satisfaction from mathematics instruction	3.11	3.09	.02	-.480	.632	-.026	6.043	2, 221	.003	.04
Satisfaction from tech-supported mathematics	3.27	3.35	-.08	-.523	.601	-.048	23.160	2, 221	.000	.17
Satisfaction from instructional design	3.08	3.00	.08	-1.721	.087	-.177	19.563	2, 221	.000	.14
Overall attitudes toward mathematics	3.06	3.17	-.11	.834	.405	.042	21.817	2, 221	.000	.16
Overall motivation to learn mathematics	3.10	3.08	.02	-1.205	.230	-.078	82.186	2, 221	.000	.42
Overall learner satisfaction	3.15	3.14	.01	-1.489	.138	-.092	36.292	2, 221	.000	.24

a: posttest mean scores for control group; b: posttest mean scores for treatment group, * Indicates statistically significant mean differences ($p<.05$).

The magnitude of the group difference in satisfaction from technology-supported mathematics instruction was -.048, and the difference was not statistically significant: $t(224) = -.523, p=.601$ when controlling for the effect of pretest scores. Likewise, the magnitude of the group difference in satisfaction from instructional design was -.177, and the difference was not statistically significant: $t(224) = -1.721, p=.087$ when controlling for the effect of pretest scores. Finally, when controlling for the effect of pretest scores, the magnitude of the group difference in overall learner satisfaction from college algebra learning experience was -.092, and the difference was not statistically significant: $t(224) = -1.489, p=.138$. Although the differences were not statistically significant between traditional and redesigned college algebra sessions, students enrolled in redesigned college algebra sessions reported higher satisfaction from technology-supported mathematics which is not surprising because of the extensive infusion of instructional and learning technologies in mathematics education.

Conclusion

Technology-infused course redesign efforts supported by the NCAT have impacted thousands of college level students who enroll in courses that are impacted by high enrollment, high failure and high dropout rates. College algebra is one of these courses, and institutional reports submitted to the NCAT for program evaluations hold promise for increasing academic achievement by reducing failure and dropout rates in college algebra classrooms. However, many questions need to be answered about these why redesign efforts yield better or equivalent student learning outcomes after all teaching practices and dynamics are modified through the extensive use of learning technologies. The main purpose of this paper was to answer some of those questions which were related to the psychosocial factors of learning mathematics. Changes in students' attitudes toward mathematics, motivation to learn mathematics, and satisfaction from

the mathematics learning experiences in both redesigned and traditionally-taught college algebra classrooms were examined. Within-group comparisons were made through paired-samples t-tests, and between-group comparisons were made through multiple regression analyses.

Within-group analyses revealed that attitudes toward technology-supported mathematics, beliefs about learning mathematics, and overall attitudes toward learning mathematics changed statistically significantly throughout the semester in traditionally-taught college algebra classrooms, but the magnitude of the change was negative. Therefore, the traditionally-taught college algebra impacts students' attitudes toward technology-supported mathematics, overall attitudes toward mathematics, and beliefs about learning mathematics negatively, whereas motivation to learn mathematics, and satisfaction from the overall mathematics learning experiences do not change significantly in traditionally-taught college algebra classrooms during a four-month period.

On the other hand, redesign efforts statistically significantly impacted students' attitudes toward mathematics, students' attitudes toward technology-supported mathematics, learners' extrinsic motivations to learn mathematics, and satisfaction from the mathematics learning experiences in college algebra settings. However, all the statistically significant changes were negative in magnitude. This suggests that the Emporium redesign efforts at the research institution negatively impacted students' attitudes toward mathematics, toward technology-supported mathematics, their extrinsic motivation to learn mathematics, and their satisfaction from the mathematics learning experiences in college algebra sessions. Redesigned efforts in college algebra do not significantly affect learners' beliefs about learning mathematics, their intrinsic motivation to learn mathematics, their overall motivation to learn mathematics, and their satisfaction from mathematics instruction. Only intrinsic motivation scores changed positively.

Regarding the between-group comparisons, only attitudes toward mathematics, and attitudes toward technology-supported mathematics were significantly different between redesigned and traditionally-taught college algebra sessions. Learners enrolled in the traditionally-taught college algebra sessions had a higher attitudes toward mathematics mean score, whereas students enrolled in the redesigned college algebra sessions had a higher mean score for attitudes toward technology-supported mathematics. Students' beliefs about learning mathematics, motivation to learn mathematics and satisfaction from the overall mathematics learning experience were not significantly different between the two instruction modes. Although all the analyses revealed useful information, further analyses are needed to examine the relationship between college redesign efforts and student learning outcomes.

Limitations and Need for Future Research

In this research paper, it was assumed that sampling, attrition rate, location, honesty of participants, and instrumentation did not affect participants' responses. The following limitations might be considered for this research paper: convenience sampling which is vulnerable for generalizations, loss of participants due to high drop-out rates in college algebra sessions, and the difference between the physical settings of traditionally-taught college algebra and redesigned college algebra sessions in which data were collected.

In addition, the limitations of the study might be summarized as (a) sampling procedure because participation in the study was limited to the students who enrolled in college algebra courses at a single Midwestern university, and students who enrolled in the college algebra, then either failed or withdrew from the course, and subsequently reenrolled in the course, and students who either completed pretest only or posttest only were excluded from the study; (b) limitations of dependent variables and examination of those variables only in college-level mathematics

learning environments; (c) the results of the study were limited in terms of external validity, and the results of this study only generalizable to the students who enroll in college algebra sessions at a higher education institution which adopts the same NCAT redesign model and uses similar learning technology tools and teaching strategies; and (d) the other important limitation has to do with time. The traditionally-taught college algebra meets three times a week for 50 minute lectures, whereas redesigned college algebra requires only one 50 minute lecture, but two 75 minute interactive learning lab sessions each week.

This manuscript only focused on changes in psychosocial factors of learning in two different formats for college algebra courses, and academic achievement and the relationship between these dependent variables were not in the scope of this research paper. Therefore, more comprehensive and exploratory analyses which involve learners' incoming mathematics knowledge and end-of-semester academic achievement along with psychosocial factors of learning in redesigned college algebra sessions will be highly informative.

CHAPTER 5

DISCUSSION

This dissertation was developed using a manuscript-based dissertation approach, which is also called a European style dissertation, and consists of multiple manuscripts which were separately developed, but conceptually related. The ultimate goal of the dissertation was to examine possible changes in students' affective domains by focusing on psychosocial factors of learning through a reliable and valid data collection tool in the context of a redesigned college algebra course. College algebra is one of the college level introductory courses that is taught nationwide; thousands of students enroll in this course annually. However, a significant percent of these students fail or withdraw because of the ever persisting problems of college algebra such as high enrollment rates, ill structured instructional practices, ineffective teaching methods and the changing mathematical needs of learners and society (Barker, Bressoud, Epp, Ganter, Haver, & Pollatsek, 2004; Edwards, 2011; Gordon, 2004, 2008, 2013; Mayes, 2004). Many of the students who fail or withdraw for different reasons retake college algebra in the future as a requirement for graduation or as a prerequisite for an advanced level mathematics course (Benford & Gess-Newsome, 2006; Brewer & Becker, 2010; Gordon, 2008; Haver et al., 2007; Herriott, 2006; Mayes). Different remediation strategies and methods have been used to address these problems of college algebra and to increase the quality of student learning outcomes because as Small (2002, 2006) argues, traditional college algebra courses do not provide desired student learning outcomes. Through the years intensity models, redesigned curricula, project-based and contextual learning, acceleration models and technology integration models have been implemented for better learning outcomes in college algebra (Alexander, 1996; Berryman & Short, 2010; Epper & Baker, 2009; Lazari, 2007).

The new approach to addressing problems of college algebra and increasing academic achievement and retention rates along with reduced cost is course redesign supported and guided by the National Center for Academic Transformation (NCAT). NCAT offers six different course redesign models, and each utilizes learning technologies extensively to address the ever persistent problems of college level introductory courses that suffer from high enrollment rates, low academic achievement and low retention rates. Based on course redesign initiative reports prepared by participating institutions for NCAT, among these six models, the mathematics Emporium model appears to yield the best student learning outcomes in introductory level mathematics courses including college algebra. The mathematics Emporium requires changes in the instructional dynamics of traditionally-taught college algebra. It eliminates all instructor-led lectures, and moves the college algebra instruction to a student-centered learning environment in which constructivist principles of learning such as group work are supported (NCAT, 2015e). The new learning environment is called an interactive learning lab which is a fully equipped computer lab that allows students to work collaboratively and to work with instructional software that enables students to access course materials outside of the campus, to study at their own pace, and to get immediate feedback (MSCRI, 2011).

Under the scope of the Missouri Statewide Course Redesign Initiative, one research university in the Midwest redesigned its college algebra course by implementing the mathematics Emporium. Almost all institutions which had used the mathematics Emporium model to redesign college level introductory level mathematics courses reported equivalent and/or better student learning outcomes that included increased academic achievement, increased retention rates, and cost effectiveness. Final exam scores and GPA were used as indicators of academic achievement, and withdrawal rates were used as indicators of retention rates. However,

some institutions anecdotally reported better student attitudes towards subject matter, increased motivation, and increased faculty and student satisfaction, which variables were not examined or requested by NCAT, so empirical research on these psychosocial factors of learning is severely limited in these redesigned learning environments even though they might help researchers explain why the redesigned learning environments result in better and/or equivalent student learning outcomes when compared to traditional learning settings. Based on this, three questions were considered: (a) the existence of a detailed and comprehensive literature review that outlined technology integration efforts that include course redesign - the mathematics Emporium - and their outcomes; (b) the existence of a reliable and valid instrument developed to consider the dynamics of the mathematics Emporium on measuring students' attitude towards mathematics, motivation to learn mathematics, and satisfaction from the mathematics instruction; and (c) the extent to which those psychosocial factors changed significantly between traditionally-taught and redesigned college algebra contexts. Three manuscripts developed under the scope of this dissertation addressed these three questions to better understand the role of psychosocial factors of learning on the outcomes of the mathematics Emporium delivery model in the college algebra context.

The first manuscript that is titled "Course Redesign and Infusion of Educational Technology into College Algebra" was a comprehensive overview that outlined instructional and learning technologies practices and outcomes in college algebra courses. The manuscript introduced a definition of college algebra and its purpose in addition to discussing the problems of college algebra. The manuscript outlined high enrollment rates, low academic achievement and low retention rates, and instructional deficiencies as problems of college algebra that need immediate attention. Furthermore, the manuscript comprehensively discussed the learning

technology integration efforts for better student learning outcomes in the context of college algebra as a result of an extensive literature review. It summarized that calculators, supplemental instruction, computer-assisted instruction, web-based learning, and learning management systems had been used effectively in college algebra and had resulted in better student learning outcomes in many research settings. However, they have not been universally adopted. The manuscript also introduced the course redesign approach by putting more emphasis on the mathematics Emporium, and presented the story of the research institution which was labeled “Urban U”. In addition to introducing the six different course redesign models, the manuscript discussed changes that the mathematics Emporium model requires with an in-depth description of instructional format and changes in course structure, the physical learning environment and extensive integration of instructional and learning technologies. To sum, the manuscript was a comprehensive literature review of integrating instructional and learning technologies into college algebra which combines all of the aforementioned concepts. The manuscript honed the discussions on instructional and learning technologies to the course redesign models, specifically to the mathematics Emporium, which is the main research context of the dissertation.

The second manuscript, titled “Measurement of Psychosocial Factors of Learning in the Math Emporium: Scale Development and Assessment”, addressed the second question, and focused on developing and assessing psychometric properties of a new instrument that measures students’ attitude towards mathematics, motivation to learn mathematics, and satisfaction from the instructional design and learning experiences in the redesigned college algebra context. The manuscript included a rationale for developing a new instrument, and presented psychometric properties of the instrument including validity evidences, internal replicability and reliability results. A comprehensive examination of mathematics education literature revealed a lack of

empirical research on psychosocial factors of learning in college level mathematics courses although it is emphasized that these factors are as important as they are in K-12 education. There are various scales developed to measure students' attitude towards mathematics, motivation to learn mathematics and satisfaction from the instructional design and learning experiences (e.g. Conley & Karabenick, 2006; Davis, 2014; Fennema & Sherman, 1976; Githua & Mwangi, 2003; Keengwe, 2007; Pierce, Stacey, & Barkatsas, 2007; Savery, 2002; Tapia & Marsh, 2004; Wu, Tennison, & Hsia, 2010). These instruments, however, were developed with instructional practices and dynamics of education at the K-12 level, and most used traditional stems for attitude, motivation and satisfaction. The scale, Psychosocial Factors of Learning in Redesigned Introductory College Mathematics (PFL-RICM) was originally developed as part of the Learners' Perceptions of Redesigned College Mathematics (LP-RCM) scale. In the scope of this paper, three subscales: attitudes toward mathematics, motivation to learn mathematics, and satisfaction from the mathematics instruction and learning experiences that form PFL-RICM scale were analyzed. Extensive and comprehensive literature review on measured variables, and instructional practices and changes that the Emporium model requires were considered while developing the scale stems. The manuscript summarized content validity, face validity, respondent process validity evidences and arguments collected at the time of the PFL-RICM scale development, and reported internal structure validity and internal replicability examined through exploratory factor analysis (EFA) along with Cronbach's Alpha internal consistency reliability coefficients. The manuscript analyzed 49 items that targeted attitudes toward mathematics (22 items), motivation to learn mathematics (10 items), and satisfaction from the mathematics instruction and learning experiences (17 items) through exploratory factor analyses and internal replicability analysis. As a result of phase one exploratory factor analyses, the

attitude subscale consisting of 17 items was retained with a three-factor structure that explained 58% of the variance in total. The factors were (a) attitudes toward mathematics (29% of the variance), (b) attitudes toward technology-supported mathematics (19% of the variance), and (c) learners' beliefs about learning mathematics (10% of the variance). The six-item motivation subscale was retained with a two-factor structure that explained 37% of the variance. The factors were (a) intrinsic motivation (28% of the variance), and (b) extrinsic motivation (9% of the variance). Finally, the 12-item satisfaction was retained with a three-factor structure that explained 50% of the variance. The factors were (a) satisfaction from mathematics instruction (15% of the variance), (b) satisfaction from course redesign efforts (28% of the variance); and (c) overall satisfaction from the mathematics learning experiences (7% of the variance).

As Osborne and Fitzpatrick (2012) suggested, internal replicability analyses were completed in phase two. Configural invariance, and structural invariance properties of the PFL-RICM scale were examined. As a result of phase two, the three-factor attitude subscale that explained 53% of the variance, the two-factor motivation subscale that explained 33% of the variance, and the three-factor satisfaction subscale which explained 43% of the variance were retained. Two items, “[u]sing technology for learning mathematics can be a little scary” and “I am satisfied with the accessibility of course grades outside of class” failed to satisfy configural invariance or structural invariance criteria, so they should be critically examined in future implementations.

Reliability analyses revealed that reliability coefficients were at a desired level ($\alpha > .70$), but extrinsic motivation to learn factor ($\alpha < .70$). In conclusion, psychometric analyses of the PFL-RICM scale indicated that the scale is a valid and reliable instrument that can be used not only in higher education, but also in K-12 mathematics education context because current attitude,

motivation and satisfaction scales do not specifically address learning technology integration efforts in education.

The third manuscript, titled “Impacts of the Math Emporium Delivery Model on Psychosocial Factors of Learning in College Algebra,” was a comparative study which examined how students’ attitude towards mathematics, motivation to learn mathematics, and satisfaction from the instructional design and learning experiences changed in traditionally-taught college algebra, and in redesigned college algebra sections throughout the semester. The manuscript also compared the aforementioned psychosocial factors in traditionally-taught and redesigned college algebra settings. Paired samples t-tests were used for within group comparisons, whereas multiple regression was used for between-group comparisons. The results of the manuscript revealed that students’ attitude towards technology-supported mathematics, beliefs about learning mathematics, and overall attitude towards mathematics changed significantly in traditionally-taught college algebra settings in a four-month period. On the other hand, students’ attitude towards mathematics, attitude towards technology-supported mathematics, extrinsic motivation to learn mathematics, satisfaction from technology-supported mathematics, satisfaction from instructional design, overall attitude towards mathematics, and overall learner satisfaction changed significantly in redesigned college algebra settings. However, all mean changes were negative in magnitude which resulted in the average of posttest scores were lower than the mean of pretest scores for each subscale in both settings. Finally, the manuscript compared posttest scores while controlling for the pretest scores in both learning settings. Multiple regression analysis revealed that students who enrolled in traditional college algebra sections had significantly higher attitude towards mathematics mean score ($M=2.82$) than students who enrolled in redesigned college algebra sections ($M=2.79$), whereas students who

enrolled in redesigned college algebra sections had significantly higher attitude towards technology-supported mathematics mean score ($M=2.98$) than students who enrolled in traditionally-taught college algebra sections ($M=2.85$) at the end of the four-month period after controlling for preexisting attitude scores. The study revealed that instructional practices students experienced not only in traditionally-taught college algebra, but also in redesigned college algebra negatively impacted students' attitude towards mathematics, attitude towards technology-supported mathematics, beliefs about learning mathematics, extrinsic motivation to learn mathematics, satisfaction from technology supported mathematics, and satisfaction from the instructional design of college algebra, and students' attitude towards mathematics and attitude towards technology-supported mathematics were significantly different in both instructional settings. These findings support Sundre, Barry, Gynnild, and Ostgard (2012) who reported "students change their attitudes and goals during the course of the semester, with some changing more than others" (p. 2). Literature also includes studies (e.g. Brewer & Becker, 2010; Ernst, Taylor, & Peterson, 2005; Stillson & Alsup, 2003, Yerushalmy, 2000) that explained the impact of technology integration on the affective domain of learners and psychosocial factors of learning. Thus, statistically-significant higher scores of attitude towards technology-supported mathematics in redesigned college algebra settings were not surprising, but important because this might be one of the factors that explain the increased academic achievement and retention rates in redesigned college algebra classrooms.

Limitations

In this study, it was assumed that sampling, attrition rate, location, honesty of participants and instrumentation did not affect participants' responses. However, there are several limitations that threaten the internal and external validity of research results. Reliability analyses, for

example, revealed that reliability of subscales that specifically focus on motivation and satisfaction was not at a desired level. Attrition rate was really high in the college algebra at the time of data collection. Therefore, mortality was also a threat to internal validity of the research results. A significant number of participants were excluded due to incomplete surveys, incomplete posttests, not applicable responses etc. Although the number of “not applicable” responses was not high, exclusion of these participants from the sample should also be considered as a limitation. The researcher was not able to manipulate sampling procedure, and assigning participants into control (redesigned college algebra) and treatment (traditional college algebra) groups was beyond the researcher’s control. During the pilot testing, half of the college algebra sections were taught in the redesigned format and half of the sections were taught in a traditional format over the course of a semester. Although the survey was administered the first week of the semesters, and participants were tracked not to complete the survey more than once in two different sections, it was not too late to switch between redesigned sections and traditionally-taught sections of college algebra during pilot implementation of the course redesign. Therefore, if a participant was not satisfied or had difficulties adjusting to the new mode of instruction—redesigned college algebra—then she/he was able to drop the course and reenroll in a traditionally-taught college algebra section if there was space. On the other hand, at the time of enrollment, students knew the schedules and teaching format of the courses especially because the length and locations of the sections were different. In other words, students who enrolled earlier had a chance to choose a section they wanted to enroll in, and students who enrolled late might have had to enroll in redesigned sections due to lack of available space in traditionally-taught sections of college algebra. The class-schedules, time spent in the classroom and location of the instructions were also threats to validity of research

results because traditional college algebra required three 50-minute, face-to-face, instructor-led teaching sections per week, whereas redesigned college algebra required two 75-minute meetings in the interactive learning lab and one 50-minute session in face-to-face class meetings. The number of the graduate teaching assistants who managed the teaching and learning practices in the redesigned sections under the supervision of the main adviser is also a limitation of this study. Finally, twenty-two paired sample t-tests were run to test the hypotheses over the same sample. This inflated number of t-tests increased the likelihood of finding a significant outcome when one did not exist. This was also considered a limitation of the study. Thus it was suggested to evaluate study outcomes under the shade of inflated risk of Type I error, which can be defined as the likelihood of rejecting the null hypothesis when it is true (Abdi, 2007).

In summary then, limitations were:

- Reliability of the instrument
- Attrition rates
- Exclusion of Not Applicable responses
- Time, length, location and physical learning environment of the sessions
- Class schedules and time spent in the classroom
- Uncontrollable non-randomized participant assignments during pilot implementation
- Number of instructors and graduate teaching assistants
- Inflated number of test runs.

Suggestions for Future Research

The findings of the dissertation indicated a conflict between negative changes in psychosocial factors of learning and positive changes in student learning outcomes in redesigned

college algebra settings. Mathematics education literature emphasizes a strong positive correlation between psychosocial factors of learning and student learning outcomes (i.e. Fenster, 1992; Hatem, 2010; Kim, 2006; Kottke, 2000; Scott, 2002; Steinmayr & Spinath, 2009). Despite the negative changes in students' attitude, beliefs, motivation, and satisfaction in redesigned college algebra settings, the research institution reported increased academic achievement and retention rates to the NCAT. Although such desired learning outcomes can be attributed to many different factors and practices in learning environments, one might be the fact that students reported significantly higher scores of attitude towards technology-supported mathematics in redesigned college algebra settings. Therefore, future research might focus on the impacts of the changes that course redesign requires and investigate the relationship between how each course redesign effort such as the changing role of students and instructors, heavily using technology for learning and assessment, immediate feedback, on-demand help opportunities, and outcomes of collaborative learning activities affect student learning outcomes. Academic achievement, for example, was not examined as part of this dissertation, and a research study that investigates the relationship between psychosocial factors of learning and academic achievement in redesigned college algebra sessions might be very informative. Finally, psychometric properties of the PFL-RICM scale were examined through exploratory factor analysis and internal replicability analysis, and a replication study that utilizes confirmatory factor analysis for the scale might be informative for the validity and reliability of the PFL-RICM scale. Also, significance correction methods might be used to control the number of test run, and to minimize the risk of having Type-I error.

APPENDIX

THE PSYCHOSOCIAL FACTORS OF LEARNING IN REDESIGNED INTRODUCTORY MATHEMATICS INVENTORY

The Psychosocial Factors of Learning in Redesigned Introductory Mathematics (PFL-RICM)^{ab}	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Not Applicable
Attitudes toward mathematics						
1. I feel a definite positive reaction to mathematics; it's enjoyable.	0	0	0	0	0	0
2. I have always enjoyed studying mathematics.	0	0	0	0	0	0
3. I am happier in a mathematics class than in any other class.	0	0	0	0	0	0
4. Mathematics is very interesting to me.	0	0	0	0	0	0
5. I approach math with a feeling of hesitation, resulting from a fear of not being able to do mathematics.*	0	0	0	0	0	0
6. I prefer to avoid mathematics classes, if possible.*	0	0	0	0	0	0
7. I feel comfortable with the delivery methods of course content in mathematics courses.	0	0	0	0	0	0
8. Using technology increases my proficiency in mathematics.	0	0	0	0	0	0
9. Using technology stimulates my interest in mathematics.	0	0	0	0	0	0
10. Technology-supported mathematics education helps me to learn mathematics better.	0	0	0	0	0	0
11. I like mathematics that challenges me.*	0	0	0	0	0	0
12. Using technology for learning mathematics can be a little scary.*	0	0	0	0	0	0
13. If I use technology in mathematics, I will not learn as well.*	0	0	0	0	0	0
14. Using technology gets in the way of learning mathematics.*	0	0	0	0	0	0
15. Please mark the Disagree option.	0	0	0	0	0	0
16. I think I will do better in mathematics courses if interactive learning activities are used.	0	0	0	0	0	0
17. I wish I had more opportunities to engage in collaborative learning activities in class.	0	0	0	0	0	0
18. I would be happy if my learning process were evaluated in a prompt and continuous manner throughout the mathematics course.	0	0	0	0	0	0
19. My attitudes toward mathematics is based primarily on...	0	0	0	0	0	0
A) my past success (or lack thereof) in mathematics.						
B) the instructional strategies that I have been exposed to in mathematics courses.						
C) my satisfaction (or lack thereof) with my mathematics instructors.						
D) the relevance (or lack thereof) of mathematics to my academic interests.						
E) the quality of the mathematics textbooks I have used.						

Table continues...

THE PSYCHOSOCIAL FACTORS OF LEARNING IN REDESIGNED INTRODUCTORY
MATHEMATICS INVENTORY

The Psychosocial Factors of Learning in Redesigned Introductory Mathematics (PFL-RICM)^{ab} (Cont..)	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Not Applicable
Motivation to learn mathematics						
20. The methods used in mathematics education affect my motivation.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
21. I have to study harder than my classmates to understand mathematics concepts.*	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
22. The mathematics I learn is more important to me than the grade I receive.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
23. I like to perform better than other students on mathematics tests.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
24. I feel more motivated when I receive immediate feedback.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
25. Earning a good mathematics grade is more important to me than understanding the concepts.*	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Satisfaction in redesigned college level mathematics courses						
26. I am satisfied with the methods used to deliver course content in mathematics courses.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
27. I am satisfied with the overall quality of teaching experiences in mathematics classrooms.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
28. Mathematics instruction needs to be improved.*	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
29. I am satisfied with my mathematics content proficiency (knowledge).	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
30. The mathematics instruction I have had so far causes me to question my mathematics ability.*	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
31. Please mark the Agree option.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
32. I am satisfied with the opportunities I have to participate and share my ideas during class activities.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
33. I am satisfied with the accessibility of course materials outside of class.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
34. I am satisfied with the accessibility of course grades outside of class.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
35. I am satisfied with the interactive group activities in mathematics classrooms.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
36. I am satisfied with the overall quality of immediate feedback opportunities in mathematics.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
37. I am satisfied with the overall quality of my formal mathematics experiences.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
38. Greater use of learning technologies in the mathematics classroom might increase my overall satisfaction with mathematics courses.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Notes: a. Starred items need to be reverse coded; b. Items 15 and 31 are random responding control items

REFERENCES

- Abdi, H. (2007). The Bonferonni and Šidák corrections for multiple comparisons. In N. J. Salkind (Ed.), *Encyclopedia of measurement and statistics* (pp. 103-107). Thousand Oaks, CA: Sage.
- Aichele, D. B., Francisco, C., Utley, J., & Wescoatt, B. (2011). Computer-aided college algebra: Learning components that students find beneficial. *MathAMATYC Educator*, 2(2), 12-19.
- Aiken, L. R. (1970). Attitudes toward mathematics. *Review of Educational Research*, 40(4), 551-596.
- Alexander, M. (1996). College Algebra in an open classroom connecting teachers and technology. In *Electronic proceedings of the ninth annual international conference on technology in collegiate mathematics (ICTCM-II)*. Reno, NV, November 7-10, 1996.
- Allen, M., Bourhis, J., Burrell, N., & Mabry, E. (2002). Comparing student satisfaction with distance education to traditional classrooms in higher education: A meta-analysis. *The American Journal of Distance Education*, 16(2), 83-97.
- American Mathematical Association of Two-Year Colleges (AMATYC). (2004). *Beyond crossroads: Implementing mathematics standards in the first two years of college*. Memphis, TN: American Mathematical Association of Two Year Colleges.
- Armington, T. (2002). *Best practices in developmental mathematics*. Metuchen, NJ: Mathematics Special Professional Interest Network.
- Bargagliotti, A., Botelho, F., Gleason, J., Haddock, J., & Windsor, A. (2012). The effectiveness of blended instruction in core postsecondary mathematics courses. *International Journal for Technology in Mathematics Education*, 19(3), 83-94.

- Barker, W., Bressoud, D., Epp, S., Ganter, S., Haver, B., & Pollatsek, H. (2004). *Undergraduate programs and courses in the mathematical sciences: CUPM curriculum guide*. Washington: DC. Mathematical Association of America.
- Barton, S. (2000). What does the research say about achievement of students who use calculator technologies and those who do not?. In P. Bogacki, E. D. Fife, & L. Husch (Eds.), *Electronic proceedings of the thirteenth annual international conference on technology in collegiate mathematics*. Retrieved July 12, 2014, from <http://archives.math.utk.edu/ICTCM/EP-13.html>.
- Benford, R., & Gess-Newsome, J. (2006). Factors affecting student academic success in gateway courses at Northern Arizona University (ERIC Document Reproduction Service No. ED495693).
- Berryman, T. G., & Short, P. M. (2010). Leading developmental education redesign to increase student success and reduce costs. *Student Access, Finance, and Success in Higher Education*, 4(4), 106-114.
- Biner, P., Barone, N., Welsh, K., & Dean, R. (1997). Relative academic performance and its relation to facet and overall satisfaction with interactive telecourses. *Distance Education*, 18(2), 318-326.
- Blackboard Inc. (2014) *Learning insight*. Retrieved on November 2, 2014, from <http://www.blackboard.com/higher-education/learning-solutions/learning-insight.aspx>
- Blair, R. M., Kirkman, E. E., & Maxwell, J. W. (2013). *Statistical abstract of undergraduate programs in the mathematical sciences in the United States: Fall 2010 CBMS survey*. Washington, DC: MAA Reports

- Brewer, D. S., & Becker, K. (2010). Online homework effectiveness for underprepared and repeating college algebra students. *Journal of Computers in Mathematics and Science Teaching*, 29(4), 353-371.
- Brophy, J. (1987). Socializing students' motivation to learn. *Advances in Motivation and Achievement*, 5, 181-210.
- Brown, S. (2011). *Measure of shape: Skewness and kurtosis*. Personal collection of S. Brown, Tompkins Cortland Community College, Dryden, NY: Oak Road Systems.
- Burn, H. E. (2012). Factors that shape curricular reasoning about college algebra reform. *MathAMATYC Educator*, 4(1), 23-28.
- Cardetti, F., & McKenna, P. J. (2011). In their own words: Getting pumped for calculus. *PRIMUS*, 21(4), 351-363.
- Coe, R., Aloisi, C., Higgins, S., & Major, L. E. (2014). *What makes great teaching? Review of the underpinning research*. London, UK: Sutton Trust. Retrieved May 21, 2015, from <http://www.suttontrust.com/wp-content/uploads/2014/10/What-Makes-Great-Teaching-REPORT.pdf>
- Conley, A. M., & Karabenick, S. A. (2006). *Construct validity issues in the measurement of motivation to learn*. Paper presented at the Biennial Meeting of the Society for Research on Adolescence, San Francisco, CA. Retrieved October 6, 2014, from http://www.education.uci.edu/person/conley_a/docs/SRA06Conley.pdf
- Csikszentmihalyi, M., & Wong, M. M. H. (2014). Motivation and academic achievement: The effects of personality traits and the quality of experience. In M. Csikszentmihalyi (Ed.), *Applications of flow in human development and education: The collected works of Mihaly Csikszentmihalyi* (pp. 437-465). Dordrecht: Springer Netherlands.

- Curran, P. J., West, S. G., & Finch, J. F. (1996). The robustness of test statistics to nonnormality and specification error in confirmatory factor analysis. *Psychological Methods*, 1(1), 16-29.
- Daskalogianni, K., & Simpson, A. (2000). Towards a definition of attitude: The relationship between the affective and the cognitive in pre-university students. In T. Nakahara, & M. Koyama (Eds.), *Proceedings of the Conference of the International Group for the Psychology of Mathematics Education* (PME). Paper presented at 24th PME Conference, Hiroshima, Japan, 23-27 July (pp. 217-224).
- Davis, A. M. (2014). *Measuring student satisfaction in online math courses*. (Unpublished doctoral dissertation). University of Kentucky, Lexington: KY.
- Demiroz, E. (in progress). Measurement of psychosocial factors of learning in college-level mathematics courses: Validity and reliability analyses. Manuscript is under review.
- Edwards, B. (2011). A tale of a change initiative: Revitalizing college algebra program of the Mathematical Association of America. In S. L. Ganter, & W. E. Haver (Eds.), *Partner discipline recommendations for introductory college mathematics and the implications for college algebra* (pp. 49-59). Washington, DC: Mathematical Association of America.
- Epper, R. M., & Baker, E. D. (2009). Technology solutions for developmental math: An overview of current and emerging practices. *Journal of Developmental Education*, 26(2), 4-23.
- Ernest, P. (1991). *The philosophy of mathematics education*. London: Falmer Press.
- Ernst, J. V., Taylor, J. S., & Peterson, R. E. (2005). Tech-know: Integrating engaging activities through standards-based learning. *The Technology Teacher*, 65(2), 15-18.

- Fabrigar, L. R., Wegener, D. T., MacCallum, R. C., & Strahan, E. J. (1999). Evaluating the use of exploratory factor analysis in psychological research. *Psychological Methods*, 4(3), 272.
- Fennema E., & Sherman, J. A. (1976). Fennema-Sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males. *Journal for Research in Mathematics Education*, 7(5) 324-326.
- Fenster, M. J. (1992). Statistics courses and adult learners: Assessing potential problems. *Journal of Studies in Teaching Careers*, 14, 11-22.
- Fowler, W., & Hasebrook, J. (2001). *Proceedings from WebNet 2001: World Conference on the WWW and Internet*. (Orlando, FL, October 23-27, 2001). Norfolk, VA: Association for the Advancement of Computing in Education (ERIC #ED466945).
- Fox, W. P., & West, R. D. (2001). College algebra drills or applications?. *Problems, Resources, and Issues in Mathematics Undergraduate Studies*, 11(1), 89-96.
- Frame, B. C. (2012). *Developmental mathematics in two-year community colleges and student success*. (Unpublished doctoral dissertation). University of Montana, Missoula, MT.
- Furr, M. R., & Bacharach, V. R. (2014). *Psychometrics: An introduction* (2nd ed.). Thousand Oaks, CA: Sage.
- Ganter, S. L., & Haver, W. E. (2011). *Partner discipline recommendations for introductory college mathematics and the implications for college algebra*. Washington, DC: Mathematical Association of America.
- Gardner, R. C. (2007). Motivation and second language acquisition. *Porta Linguarum*, 8, 9-20.
- Garza, J., Havlak, K., Riggs, E., & White, P. (2000). Development of a computer-based college algebra course. (ERIC Document Reproduction Service No. ED 459 078.).

- Gifford, B. R. (1996). *Mediated learning: A new model of technology-mediated instruction and learning*. Mountain View, CA: Academic Systems Corporation.
- Githua, B. N., & Mwangi, J. G. (2003). Students' mathematics self-concept and motivation to learn mathematics: Relationship and gender differences among Kenya's secondary-school students in Nairobi and Rift Valley provinces. *International Journal of Educational Development*, 23(5), 487-499.
- González-Muñiz, M., Klingler, L., Moosai, S., & Raviv, D. (2012). Taking a college algebra course: An approach that increased students' success rate. *Primus*, 22(3), 201-213.
- Gordon, S. P. (2004). Mathematics for the new millennium. *The International Journal of Computer Algebra in Mathematics Education*, 11(2), 37-44.
- Gordon, S. P. (2008). What's wrong with college algebra? *Primus*, 18(6), 516-541.
- Gordon, S. P. (2013). Comments on mathematics education: The mathematics curriculum must evolve. *Mathematics and Computer Education*, 47(2), 126-133.
- Graham, S., & Weiner, B. (1996). Theories and principles of motivation. In D.C. Berliner, & R.C. Calfee (Eds.), *Handbook of educational psychology* (pp. 63-84). New York, NY: Macmillan.
- Gunawardena, C. N., Linder-VanBerschot, J. A., LaPointe, D. K., & Rao, L. (2010). Predictors of learner satisfaction and transfer of learning in a corporate online education program. *The American Journal of Distance Education*, 24(4), 207-226.
- Hagerty, G., & Smith, S. (2005). Using the web-based interactive software ALEKS to enhance college algebra. *Mathematics and Computer Education*, 39(3), 183-194.

- Haladyna, T., Shaughnessy, J., & Shaughnessy, J. M. (1983). A causal analysis of attitude toward mathematics. *Journal for Research in Mathematics Education*, 14(1), 19–29.
<http://doi.org/10.2307/748794>
- Hannula, M. S. (2002). Attitude towards mathematics: Emotions, expectations and values. *Educational Studies in Mathematics*, 49(1), 25-46.
- Harkness, W. L., Lane, J. L., & Harwood, J. T. (2003). A cost-effective model for teaching elementary statistics with improved student performance. *Journal of Asynchronous Learning Networks*, 7(2), 8-17.
- Hart, L. E. (1989). Describing the affective domain: Saying what we mean. In D. B. McLeod, & V. M. Adams (Eds.), *Affect and mathematical problem solving: A new perspective* (pp. 37-45). New York, NY: Springer-Verlag.
- Hatem, N. (2010). *The effects of graphing calculators on student achievement in college algebra and pre-calculus mathematics courses* (Unpublished doctoral dissertation). University of Massachusetts Lowell, Lowell, MA.
- Hauk, S., & Segalla, A. (2005). Student perceptions of the web-based homework program WeBWork in moderate enrollment college algebra classes. *Journal of Computers in Mathematics and Science Teaching*, 24(3), 229-253.
- Haver, W., Small, D., Ellington, A., Edwards, B., Kays, V. M., Haddock, J., & Kimball, R. (2007). College algebra. In V. J. Katz (Ed.), *Algebra: Gateway to a technological future* (pp.33-40). Washington, DC: Mathematical Association of America.
- Heafner, T. (2004). Using technology to motivate students to learn social studies. *Contemporary Issues in Technology and Teacher Education*, 4(1), 42-53.

- Hembree, R., & Dessart, D. J. (1986). Effects of hand-held calculators in precollege mathematics education: A meta-analysis. *Journal for Research in Mathematics Education*, 17(2), 83-99.
- Herriott, S. R. (2006). Changes in college algebra. In N. Baxter Hastings, F. S. Gordon, S. P. Gordon, & J. Narayan (Eds.), *A fresh start for collegiate mathematics: Rethinking the courses below calculus* (pp. 90-100). Washington, DC: The Mathematical Association of America.
- Herriott, S. R., & Dunbar, S. R. (2009). Who takes college algebra?. *Primus*, 19(1), 74-87.
- Horton, R. M., Storm, J., & Leonard, W. H. (2004). The graphing calculator as an aid to teaching algebra. *Contemporary Issues in Technology and Teacher Education*, 4(2), 152-162.
- House, J. D., & Telese, J. A. (2008). Relationships between student and instructional factors and algebra achievement of students in the United States and Japan: An analysis of TIMSS 2003 data. *Educational Research and Evaluation*, 14(1), 101-112.
- Hurley, M., Patterson, K. L., & Wilcox, F. K. (2006). Video-based supplemental instruction: Serving underprepared students. *New Directions for Teaching and Learning*, 2006(106), 43-53.
- Jhaj, S. (n.d.) *Academic innovation and student success: PSU's student success initiative* [Blog post]. Retrieved June 21, 2015, from <https://jhaj.wordpress.com/>
- Johnson, T. M., McAlpin, V., & An, J. (2012). *Student success at UNC Charlotte: Large course redesign*. Retrieved February 21, 2014, from <http://provost.uncc.edu/sites/provost.uncc.edu/files/media/Student-Success-Vol-1-Large-Course-Redesign.pdf>

- Kearns, L. E., Shoaf, J. R., & Summey, M. B. (2004). Performance and satisfaction of second-degree BSN students in web-based and traditional course delivery environments. *Journal of Nursing Education*, 43(6), 280.
- Keengwe, J. (2007). Faculty integration of technology into instruction and students' perceptions of computer technology to improve student learning. *Journal of Information Technology Education: Research*, 6(1), 169-180.
- Keller, J. M. (1983). Motivational design of instruction. In C.M. Reigeluth (Ed.), *Instructional design theories and models: An overview of their current status* (pp. 383-434). Hillsdale, NJ: Lawrence Erlbaum.
- Kersaint, G., Dogbey, J., Barber, J., & Kephart, D. (2011). The effect of access to an online tutorial service on college algebra student outcomes. *Mentoring & Tutoring: Partnership in Learning*, 19(1), 25-44.
- Kim, H. (2006). *A Model for Predicting Performance in Introductory Statistics Courses* (Unpublished doctoral dissertation), The Pennsylvania State University, State College, PA.
- King H. J. (1997). Effects of computer-enhanced instruction in college level mathematics as determined by a meta-analysis. (Doctoral dissertation). The University of Tennessee, Knoxville, TN. *Dissertation Abstracts International*, 59(1), 114A.
- Kinney, D. P., & Robertson, D. F. (2003). Technology makes possible new models for delivering developmental mathematics instruction. *Mathematics and Computer Education*, 37(3), 315-328.

- Klein, H. J., Noe, R. A., & Wang, C. (2006). Motivation to learn and course outcomes: The impact of delivery mode, learning goal orientation, and perceived barriers and enablers. *Personnel Psychology*, 59(3), 665-702.
- Knowles, E., & Kerkman, D. (2007). An investigation of students' attitude and motivation toward online learning. *Insight: A Collection of Faculty Scholarship*, 2, 70-80.
- Kottke, J. L. (2000). Mathematical proficiency, statistics knowledge, attitudes towards statistics, and measurement course performance. *College Student Journal*, 34(3), 334-347.
- Krumrei-Mancuso, E. J., Newton, F. B., Kim, E., & Wilcox, D. (2013). Psychosocial factors predicting first-year college student success. *Journal of College Student Development*, 54(3), 247-266.
- Kulm, G. (1980). Research on mathematics attitude. In R. J. Shumway (Ed.), *Research in mathematics education* (pp. 356-387). Reston, VA: National Council of Teachers of Mathematics.
- Larson, D. K., & Sung, C. H. (2009). Comparing student performance: online versus blended versus face-to-face. *Journal of Asynchronous Learning Networks*, 13(1), 31-42.
- Lazari, A. (2007). Does the number of lectures a week make a difference in the learning of concepts and retention of students in college algebra? *Georgia Journal of Science*, 65(2), 72-75.
- Lazari, A., & Simons, K. (2001). Longer communications teaching college algebra using online software versus the traditional lecture method. *Georgia Academy of Science*. 59(4), 165-171.
- Lazari, A., & Simons, K. (2003). Teaching college algebra using supplemental instruction versus the traditional lecture method. *Georgia Journal of Science*, 61(4), 192-198.

- Lorenzo, G. (2012). A research review about online learning: Are students satisfied? Why do some succeed and others fail? What contributes to higher retention rates and positive learning outcomes? *Internet Learning*, 1(1), 45-54.
- Lumsden, L. S. (1994). *Student motivation to learn*. (ERIC Digest, No. 92). Retrieved October 4, 2014 from <http://eric.ed.gov/?id=ED370200>
- Ma, X., & Kishor, N. (1997). Assessing the relationship between attitude toward mathematics and achievement in mathematics: A meta-analysis. *Journal for Research in Mathematics Education*, 28(1), 26-47.
- Martin, D. C., & Arendale, D. R. (1992). *Supplemental Instruction improving first-year student success in high-risk courses* (2nd ed., Monograph No. 7). Columbia, SC: National Resource Center for the Freshmen Year Experience, University of South Carolina.
- Martin, D. C., & Blanc, R. (2001). Video-based supplemental instruction (VSI). *Journal of Developmental Education*, 24(3), 12-19.
- Mayes, R. (2004). Restructuring college algebra. *International Journal for Technology in Mathematics Education*, 11(2), 63-73.
- McLeod, D. B. (1992). Research on affect in mathematics education: A reconceptualization. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 575-596). New York: Macmillan.
- McSweeney, L., & Weiss, J. (2003). Assessing the math online tool: A progress report. *Mathematics and Computer Education*, 37(3), 348-357.
- Messick, S. (1989). Validity. In R. L. Linn (Ed.), *Validity* (3rd ed., pp. 13–103). New York, NY: Macmillan.

- Middleton, J. A., & Spanias, P. A. (1999). Motivation for achievement in mathematics: Findings, generalizations, and criticisms of the research. *Journal for Research in Mathematics Education*, 30(1), 65-88.
- Missouri Statewide Course Redesign initiative-MSCRI (2011), *Final project plan*. Retrieved March 16, 2013, from <http://info.umkc.edu/courseredesign/umkc-course-redesign/>
- Missouri Statewide Course Redesign initiative-MSCRI (2012), *College algebra redesign handbook*. Retrieved March 16, 2013, from <http://info.umkc.edu/courseredesign/>
- Morgan, G. (2003). *Key findings: Faculty use of course management systems*. (Vol. 2, pp. 1-6). Louisville, CO: ECAR, EDUCAUSE Center for Applied Research.
- Neale, D. C. (1969). The role of attitudes in learning mathematics. *Arithmetic Teacher*, 16(8), 631-640.
- Nolan, M. M., Beran, T., & Hecker, K. G. (2012). Surveys assessing students' attitudes toward statistics: A systematic review of validity and reliability. *Statistics Education Research Journal*, 11(2), 103-123.
- NSF - National Science Foundation (1998). *Information technology: Its impact on undergraduate science, mathematics, engineering, and technology*. Arlington, VA: National Science Foundation (NSF Report Number NSF98-82).
- Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory*. New York: McGraw-Hill.
- O'Callaghan, B. R. (1998). Computer-intensive algebra and students' conceptual knowledge of functions. *Journal for Research in Mathematics Education*, 29(1), 21-40.
- Osborne, J. W. (2008). Sweating the small stuff in educational psychology: How effect size and power reporting failed to change from 1969 to 1999, and what that means for the future of changing practices. *Educational Psychology*, 28(2), 151-160.

- Osborne, J. W. (2014). *Best practices in exploratory factor analysis*. Louisville, KY: CreateSpace Independent Publishing Platform.
- Osborne, J. W., & Fitzpatrick, D. C. (2012). Replication analysis in exploratory factor analysis: What it is and why it makes your analysis better. *Practical Assessment, Research and Evaluation, 17*(15), 1-8.
- Papanastasiou, C. (2000). Effects of attitudes and beliefs on mathematics achievement. *Studies in Educational Evaluation, 26*(1), 27-42.
- Parsons, S. J. (2004). *Overcoming poor failure rates in mathematics for engineering students: A support perspective*. Newport: Harper Adams University College. Retrieved July 16, 2014 from <http://www.hull.ac.uk/engprogress/Prog3Papers/Progress3%20Sarah%20Parsons.pdf>
- Pemberton, C. L. (2011). *Supplemental instruction (SI): Perspectives from around the world*. Retrieved June 21, 2012, from <http://info.umkc.edu/umatters/2011/03/08/si-perspectives-from-around-the-world/>
- Piaget, J. (1976). *The grasp of consciousness: Action and concept in the young child*. Cambridge, MA: Harvard University Press.
- Pierce, R., Stacey, K., & Barkatsas, A. (2007). A scale for monitoring students' attitudes to learning mathematics with technology. *Computers & Education, 48*(2), 285-300.
- Prensky, M. (2001). Digital natives, digital immigrants. *On the Horizon, 9*(5), 1-6.
- Roach, V., & Lemasters, L. (2006). Satisfaction with online learning: A comparative descriptive study. *Journal of Interactive Online Learning, 5*(3), 317-332.
- Robbins, S. B., Allen, J., Casillas, A., Peterson, C. H., & Le, H. (2006). Unraveling the differential effects of motivational and skills, social, and self-management measures from

- traditional predictors of college outcomes. *Journal of Educational Psychology*, 98(3), 598-616.
- Robbins, S. B., Lauver, K., Le, H., Davis, D., Langley, R., & Carlstrom, A. (2004). Do psychosocial and study skill factors predict college outcomes? A meta-analysis. *Psychological Bulletin*, 130(2), 261-88.
- Rochowicz Jr, J. A. (1996). The impact of using computers and calculators on calculus instruction: Various perceptions. *Journal of Computers in Mathematics and Science Teaching*, 15(4), 423-435.
- Roqueta, M. (2008). Learning management systems: A focus on the learner. *Distance Learning*, 5(4), 59-66.
- Rosenthal, D., & Weitz, R. (2012). Large-course redesign via blended learning: A post-implementation assessment across institutions. *International Journal on E-Learning*, 11(2), 189-207.
- Rugutt, J., & Chemosit, C. C. (2009). What motivates students to learn? Contribution of student-to-student relations, student-faculty interaction and critical thinking skills. *Educational Research Quarterly*, 32(3), 16-28.
- Ruthven, K. (1990). The influence of graphic calculator use on translation from graphic to symbolic forms. *Educational Studies in Mathematics*, 21(5), 431-450.
- Savery, J. R. (2002). Faculty and student perceptions of technology integration in teaching. *The Journal of Interactive Online Learning*, 1(2), 1-16.
- Schoenfeld, A.H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. In D. Grouws (Ed.), *Handbook of research on teaching and learning mathematics* (pp. 334-370). New York, NY: Macmillan.

- Schwartz, A. E. (2007). New standards for improving two-year mathematics instruction. *Education Digest: Essential Readings Condensed for Quick Review*, 73(2), 39-42.
- Scott, J. S. (2002). Modeling aspects of students' attitudes and performance in an undergraduate introductory statistics course. *Dissertation Abstracts International Section A: Humanities and Social Sciences*, 62(9-A), 2973.
- Simon, M. (2011). *The role of the researcher*. Retrieved May 21, 2016, from <http://dissertationrecipes.com/wp-content/uploads/2011/04/Role-of-the-Researcher.pdf>
- Simonson, M., Smaldino, S., Albright, M., & Zvacek, S. (2006). *Teaching and learning at a distance: Foundations of distance education* (3rd ed.). Upper Saddle River, NJ: Pearson
- Small, D. (2002). An urgent call to improve traditional college algebra programs. Summary of the conference to improve college algebra held at the U.S. Military Academy, February 7–10, 2002. *MAA Focus*, 5, 12-13.
- Small, D. (2006). College algebra: A course in crisis. In N. Baxter Hastings (Ed.), *A fresh start for collegiate mathematics: Rethinking the courses below calculus* (pp. 83-89). Washington, DC: Mathematical Association of America.
- Smith, K. B., & Shotsberger, P. G. (1997). Assessing the use of graphing calculators in college algebra: Reflecting on dimensions of teaching and learning. *School Science and Mathematics*, 97(7), 368-373.
- Steinmayr, R., & Spinath, B. (2009). The importance of motivation as a predictor of school achievement. *Learning and Individual Differences*, 19(1), 80-90.
- Stephens, L.J., & Konvalina, J. (1999). The use of computer algebra software in teaching intermediate and college algebra. *International Journal of Mathematical Education in Science and Technology*, 30(4), 483-488.

- Stillson, H., & Alsup, J. (2003). Smart ALEKS... or not? Teaching basic algebra using an online interactive learning system. *Mathematics and Computer Education*, 37(3), 329-340.
- Sun, P. C., Tsai, R. J., Finger, G., Chen, Y. Y., & Yeh, D. (2008). What drives a successful e-Learning? An empirical investigation of the critical factors influencing learner satisfaction. *Computers & Education*, 50(4), 1183-1202.
- Sundre, D., Barry, C., Gynnild, V., & Ostgard, E. T. (2012). Motivation for achievement and attitudes toward mathematics instruction in a required calculus course at the Norwegian University of Science and Technology. *Numeracy*, 5(1), 4.
- Suydam, M. N. (1976). *Electronic hand calculators: The implication for precollege education (Final Report)*. Washington, D.C.: National Science Foundation.
- Suydam, M. N. (1980). *The use of calculator in precollege education: A state of the art review*. Columbus, OH: Calculator Information Center.
- Tapia, M., & Marsh, G. E. (2004). An instrument to measure mathematics attitudes. *Academic Exchange Quarterly*, 8(2), 16.
- Taylor, J. M. (2008). The effects of a computerized-algebra program on mathematics achievement of college and university freshmen enrolled in a developmental mathematics course. *Journal of College Reading and Learning*, 39(1), 35-53.
- Taylor, S. E., & Mittag, K. G. (2001). Seven wonders of the ancient and modern quadratic world. *The Mathematics Teacher*, 94(5), 349-350, 361.
- The National Center for Academic Transformation. (2015a). *Impact on students: University of Alabama*, Retrieved June 3, 2015, from http://www.thencat.org/PCR/R2/UA/UA_FR1.htm

- The National Center for Academic Transformation. (2015b). *Impact on students: University of Central Florida*, Retrieved June 3, 2015, from http://www.thencat.org/PCR/R1/UCF/UCF_PR1.htm
- The National Center for Academic Transformation. (2015c). *Improving the quality of student learning: Tallahassee Community College*, Retrieved June 3, 2015, from http://www.thencat.org/PCR/R3/TCC/TCC_PR1.htm
- The National Center for Academic Transformation. (2015d). *Improving the quality of student learning: University of Massachusetts-Amherst*, Retrieved June 3, 2015, from http://www.thencat.org/PCR/R2/UMA/UMA_PR1.htm
- The National Center for Academic Transformation. (2015e). *Six models of course redesign*. Retrieved June 3, 2015, from http://www.thencat.org/PlanRes/R2R_ModCrsRed.htm
- The National Center for Academic Transformation. (2015f). *Summaries of other course redesign efforts*, Retrieved June 3, 2015, from <http://www.thencat.org/CommGrd/OCRP.htm>
- The National Center for Academic Transformation. (2015g). *The National Center for Academic Transformation home page*. Retrieved June 3, 2015, from <http://www.thencat.org/>
- Thiel, T., Peterman, S., & Brown, M. (2008). Addressing the crisis in college mathematics: Designing courses for student success. *Change: The Magazine of Higher Learning*, 40(4), 44-49.
- Thompson, B. (2004). *Exploratory and confirmatory factor analysis: Understanding concepts and applications*. Washington, DC: American Psychological Association.
- Thompson, C. J., & McCann, P. (2010). Redesigning college algebra for student retention: Results of a quasi-experimental research study. *MathAMATYC Educator*, 2(1), 34-38.

- Tocci, C.M., & Engelhard, G. Jr. (1991). Achievement, parental support, and gender differences in attitudes toward mathematics. *Journal of Educational Research*, 84(5), 280-286.
- Tolias, G. (1993). The effects of using graphing technology in college precalculus. *Dissertation Abstracts International*, 50(4), 1274A -1275A.
- Turner, P. M. (2009). Next generation: Course redesign. *Change: the Magazine of Higher Learning*, 41(6), 10-16.
- Twigg, C. A. (2003a). Improving quality and reducing cost: Designs for effective learning. *Change*, 35(4), 22-29.
- Twigg, C. A. (2003b). Improving learning and reducing costs: New models for online learning. *Educause Review*, 38(5), 28-38.
- Twigg, C. A. (2003c). Quality, cost and access: The case for redesign. In P.S. Pittinsky (Ed.), *The wired tower: Perspectives on the impact of the internet on higher education* (pp. 111-143). Upper Saddle River, NJ: Prentice Hall.
- Twigg, C. A. (2005). Course redesign improves learning and reduces cost. In *Policy Alert* (pp. 1-6). San Jose, CA: National Center for Public Policy and Higher Education. Retrieved May 12, 2014 from <http://files.eric.ed.gov/fulltext/ED518668.pdf>
- Twigg, C. A. (2009). *Developmental courses: An oxymoron?* Saratoga Spring, NY: National Center for Academic Transformation. Retrieved April 22, 2013 from <http://www.thencat.org/NCATPlans/Developmental%20Courses--An%20Oxymoron.pdf>
- Twigg, C. A. (2011). The math Emporium: Higher education's silver bullet. *Change: The Magazine of Higher Learning*, 43(3), 25-34.
- University of Missouri-Kansas City. (2014). *The International Center for Supplemental Instruction home page*. Retrieved April 21, 2014, from <http://info.umkc.edu/si/>

- University of Missouri-Kansas City Center for Academic Development. (2014a). *National Supplemental Instruction Report*. Retrieved April 21, 2014, from http://www.umkc.edu/asm/si/si-docs/National%20Data%20updated%20slides_09-13-2013.pdf
- University of Missouri-Kansas City Center for Academic Development. (2014b). *VSI*. Retrieved April 21, 2014, from <http://www.umkc.edu/cad/vsi/docs/VSI-Information-Sheet.pdf>
- Vallerand, R. J., Pelletier, L. G., Blais, M. R., Briere, N. M., Senecal, C., & Vallieres, E. F. (1992). The academic motivation scale: A measure of intrinsic, extrinsic, and amotivation in education. *Educational and Psychological Measurement*, 52(4), 1003-1017.
- Vaughan, N. D. (2010). A blended community of inquiry approach: Linking student engagement and course redesign. *The Internet and Higher Education*, 13(1), 60-65.
- Villarreal, L. M. (2003). A step in the positive direction: Integrating a computer laboratory component into developmental algebra courses. *Mathematics and Computer Education*, 37(1), 72-78.
- Warner, R. M. (2014). *Applied statistics: From bivariate through multivariate techniques*. Thousand Oaks, CA: SAGE Publications
- Waugh, R. F. (2002). Creating a scale to measure motivation to achieve academically: Linking attitudes and behaviours using Rasch measurement. *British Journal of Educational Psychology*, 72(1), 65-86.
- Wu, J. H., Tennyson, R. D., & Hsia, T. L. (2010). A study of student satisfaction in a blended e-learning system environment. *Computers & Education*, 55(1), 155–164.
- Wynegar, R. G., & Fenster, M. J. (2009). Evaluation of alternative delivery systems on academic performance in college algebra. *College Student Journal*, 43(1), 170-174.

- Ye, N., & Herron, S. S. (2010). A comparison of computer-based and traditional college algebra courses. *Journal of Applied Global Research*, 3(7), 40-49.
- Yerushalmy, M. (2000). Problem solving strategies and mathematical resources: A longitudinal view on problem solving in a function based approach to algebra. *Educational Studies in Mathematics*, 43(2), 125-147. Retrieved May 2, 2013 from <http://search.proquest.com/docview/62248039?accountid=14589>
- Zan, R., & Di Martino, P. (2007). Attitude toward mathematics: Overcoming the positive/negative dichotomy. In B. Sriraman (Ed.), *Beliefs and mathematics: Festschrift in honor of Guenter Toerner's 60th birthday* (pp. 197-214). Missoula, MT: Information Age Publishing.
- Zelkowski, J., & Goodykoontz, E. (2013). Student accountability in a required college calculus course. *Mathematics and Computer Education*, 47(3), 204-223.

VITA

Erdem Demiroz was born on July 15, 1981, in Luleburgaz, Kırklareli, Turkey. He received his K-8 education in village of Celaliye, and attended the computer division of a vocational high school, Anatolian Technical High School in Luleburgaz, emphasizing computer hardware and software. He graduated with honors in 2000, and in 2001, Mr. Demiroz attended the Ege University, where he earned his Bachelor of Arts in the School of Education with emphasis on computer education and instructional technologies. He graduated as a certified teacher in 2006, and immediately after, he was appointed as a research assistant at the Trakya University, School of Education, Department of Computer Education and Instructional Technologies. He worked three years at the Trakya University, and decided to pursue his education at the graduate level at the University of Missouri-Kansas City, USA.

Mr. Demiroz was accepted into the Master of Arts program with emphasis on instructional technologies in the department of Teacher Education and Curriculum Studies (formerly Curriculum and Instructional Leadership) at the University of Missouri-Kansas City in 2009. Upon completion of this degree in 2011, he started the interdisciplinary Ph.D. studies with Teacher Education and Curriculum Studies as coordinating discipline and Mathematics and Statistics as co-discipline at the same institution. He was awarded the Preparing Future Faculty Fellowship two consecutive years, and completed the College Teaching & Career Preparation Certification program as well as certification as an online instructor. He was nominated for the Outstanding Doctoral Student two years in a row, and received the award in 2016. Mr. Demiroz has taught several graduate and undergraduate courses that focus on teaching and learning technologies, creative problem solving, and educational assessment, and contributed to the field

of computer education and instructional technologies through academic publications and conference presentations during his graduate studies.

Mr. Demiroz secured a position at the Trakya University, School of Education, Department of Computer Education and Instructional Technologies. Upon completion of his degree requirements, he will continue his academic and teaching endeavors at the Trakya University, and will continue to prepare teachers with 21st century requirements, skills and competencies.