

IMPACT OF MATHEMATICS CONTENT COURSE SEQUENCE
ON *CBASE* AND *PRAXIS II* SCORES
OF ELEMENTARY TEACHER CANDIDATES

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by
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ABSTRACT

The focus of this study was to investigate the impact of the number of developmental mathematics courses and the level of algebraic integration of general education mathematics courses have on elementary teacher candidates' performance on the *CBASE* and *Elementary Praxis II: Curriculum, Instruction & Assessment*. Course work and standardized achievement test performance of 104 elementary teacher candidates at a midsize university located in the state of Missouri from 2001 to 2011 were analyzed. The files of 104 teacher candidates had the mathematics scores for the *CBASE* and the overall scores for the *Elementary Praxis II*; 65 of the files contained the mathematics score for the *Elementary Praxis II*.

Nonequivalent groups were formed by using the number of developmental mathematics courses completed, then using the level of algebraic integration in the general education mathematics course completed and, lastly, using the two combined. Developmental mathematics course work had categories of: (1) None, (2) Intermediate Algebra Only and (3) Introductory/Intermediate Algebra Sequence. General education mathematics course work had categories of: (1) Course Emphasized Algebra and (2) Course De-emphasized Algebra.

A two-way MANOVA was used to investigate the interaction of the factors of developmental mathematics course work and general education mathematics course work on

the dependent variables of mathematics scores on *CBASE* and overall scores on *Elementary Praxis II*. Furthermore, two separate follow-up analyses using ANOVA on each of the dependent variables were performed. In addition, a two-way ANOVA was performed to investigate the interaction of the two factors on the dependent variable of mathematics score on *Elementary Praxis II*.

The results of the present study found no significant differences in the mathematics scores on *CBASE*, the overall score of the *Elementary Praxis II* or the mathematics score of the *Elementary Praxis II* among the groups formed using the developmental and general education mathematics courses completed. As a result, the teacher candidates who entered college with deficiencies in mathematics or completed a general education mathematics course that de-emphasized algebra proved to not be at a disadvantage for passing the tests needed for obtaining teaching credentials in Missouri based on the available data information.

APPROVAL PAGE

The faculty listed below, appointed by the Dean of the School of Graduate Studies, have examined a dissertation titled “Impact of Mathematics Content Course Sequence on *CBASE* and *Praxis II* Scores of Elementary Teacher Candidates”, presented by Kathleen Anne Roy, candidate for the Doctor of Philosophy degree, and certify that in their opinion it is worthy of acceptance.

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CHAPTER 1

INTRODUCTION

Statement of the Problem

Elementary school teachers are key players in equipping students for a future world. In 2008, Achieve, an independent, bi-partisan, non-profit education reform organization consisting of governors and corporate leaders, released *The Building Blocks of Success: Higher-Level Math for All Students*. In the document, members warned:

Workers lacking mathematical skills limit their own prospects. In addition, if there are not enough workers in the U.S. with the necessary skill sets, the United States will lose economic development opportunities to other countries whose work forces do have them. (Achieve, 2008, p. 10)

To fully understand their role in this endeavor, elementary school teachers need to enter the field with a solid understanding of the whole spectrum of school mathematics and how it relates to the mathematics needed for life outside the classroom. Since states regulate teacher certification, institutes of higher education are charged with preparing teacher candidates in meeting state adopted mathematical competencies. As a result, these competencies influence all decisions regarding the sequence of mathematics courses to be completed by teacher candidates. Unlike the subject specific training middle school or secondary teachers receive as part of their college experience, the training elementary teachers receive involves all subjects in the elementary school curriculum. Hence, research considering the effectiveness of the mathematics course work in meeting the competencies for teaching elementary school mathematics is limited.

As the U.S. educational system developed, the primary school curriculum became increasingly more diverse. During the seventeenth century, schools were founded based on two views of student needs for the future. In Massachusetts, the main duty of the common

schools was to prepare students for being active members of their church. In contrast, the main function of public primary education in Virginia was to prepare children of less fortune for being workers of vocations mainly in agriculture (Cubberley, 1919).

More than three centuries later, the two views of students' needs for the future remain but are more complex in nature. One public school system is charged with satisfying both views. The first view has been expanded from being an involved member of their church to one of society as a whole. As a result, elementary students study other subjects such as social science, science, art and music in addition to reading, writing and arithmetic. The world that students are being groomed to be a productive member of has shifted further into the future. Since the formation of formal schooling in the United States, the number of years the average student is expected to spend in the local school system rose from 3 – 4 years to 10 – 12 years (Pulliam & Van Patten, 2007).

One of the most significant changes in the elementary school curriculum is the increased exposure to mathematics. In the beginning, reading and writing were viewed as the primary subjects with arithmetic being taught if time permitted. By the mid-nineteenth century, the subjects of numbers and arithmetic were embedded into the curriculum (Cubberley, 1919). By the end of the twentieth century, activities designed to develop a sense of numbers and operations, algebra, geometry and data analysis were recommended to be incorporated into the classroom as early as pre-kindergarten (National Council of Teachers of Mathematics [NCTM], 2000).

The increase of the study of mathematics during the elementary school years reflects the important role it plays in the future endeavors of the twenty-first century student. An understanding of rudimentary mathematical knowledge fosters voting responsibly, using

credit wisely and effective financial planning. Steen (2001) states “. . . numbers have become the chief instruments through which we attempt to exercise control over nature, over risk, and over life itself” (p. 3).

Conditions exist that suggest the demand for graduates of the U.S. P-12 educational system who obtain a solid grounding in mathematics is increasing. According to the Economics and Statistics Administration of the U.S. Department of Commerce (2011), the number of occupations in science, technology, engineering and mathematics (STEM) combined is expected to rise approximately 17.0% from 2008 to 2018, which reflects a 7.2% increase in the overall national job growth average for the same time period. During the twentieth century, the United States had attracted scientists and engineers from around the globe by offering a supportive environment for scientific inquiry and innovations unmatched by the majority of other countries. Leaders in both public and private arenas within the United States are now confronted with the reality that other countries are becoming more competitive in that effort (Committee on Prospering in the Global Economy of the 21st Century, 2007; Tapping America’s Potential, 2008). In *Rising Above the Gathering Storm, Revisited*, the members of the 2005 committee (2010) claimed “. . . with regard to the more ‘conventional’ functions of these fields it may well be that *de facto* there can no longer be domestic shortages of scientists and engineers” (p. 50).

For the U.S. educational system to increase the mathematical ability of its graduates, experts in the field have indicated the need to address two related phenomena: (1) success in higher levels of mathematics requires a strong foundation in elementary school level mathematics and (2) student achievement is directly impacted by the knowledge base of the teacher (National Commission on Teaching & America’s Future, 1996; National

Mathematics Advisory Panel, 2008a). Due to the nature of the subject, increasing the percentage of students reaching proficiency level or higher in the mathematics of the elementary school curriculum is essential (National Research Council, 2001a). In both 2007 and 2009, only 39% of U.S. fourth-graders achieved this level on the National Assessment of Educational Progress assessment (U.S. Department of Education, 2009). Ma (1999) concluded that in reference to the U.S. educational system, “It seems that low-quality school mathematics education and low-quality teacher knowledge of school mathematics reinforce each other” (p. 145). The combination of these occurrences has led to an increased interest in the mathematical preparation of teacher candidates working towards certification at the elementary school level.

Purpose of the Study

The purpose of this study is to investigate the relationship between the sequence of mathematics content courses completed by elementary teacher candidates and their performance on the mathematics strand on *College BASE (CBASE)* and the overall score on the *Elementary Education Praxis II: Curriculum, Instruction & Assessment (Elementary Praxis II)*. Additionally, the relationship between these courses and the performance on the mathematics strand on the *Elementary Praxis II* will also be examined.

This study is designed to investigate the impact two factors may have on the mathematics strand performance on *CBASE*, on the overall performance on *Elementary Praxis II* and on the mathematics strand performance on *Elementary Praxis II*. The factors are developmental mathematics course work and general education mathematics course work. The factor of developmental mathematics course work is a nominal variable with categories of (1) teacher candidates who completed no developmental mathematics course, (2) teacher candidates who

completed an intermediate algebra course only and (3) teacher candidates who completed the introductory algebra and intermediate algebra course sequence. The factor of general education mathematics course work is a nominal variable with categories of (1) teacher candidates who completed a general education mathematics course that emphasized algebra, such as college algebra and (2) teacher candidates who completed a general education mathematics course that de-emphasized algebra, such as finite mathematics. The three dependent variables are (1) mathematics scores on *CBASE*, (2) overall score on *Elementary Praxis II* and (3) mathematics score on *Elementary Praxis II*.

This study aims to provide an analysis of elementary teacher candidates' mathematics score on the *CBASE*, overall score on *Elementary Praxis II* and mathematics score on *Elementary Praxis II* from a single institution of higher education. Course work and standardized achievement test performance of elementary teacher candidates at a midsize university located in the state of Missouri over a ten year period from 2001 to 2011 will be analyzed to determine the presence of main and interaction effects of developmental and general education mathematics course work.

Research Questions

The research questions for this study were designed to gain insight into the impact the mathematical content preparation (developmental and general education) of elementary teacher candidates has on *College BASE (CBASE)* and *Elementary Education Praxis II: Curriculum, Instruction & Assessment (Elementary Praxis II)* performance. These tests were selected due to their usage as gateways for entrance into undergraduate teacher education programs (*CBASE*) and for entrance into the elementary education teaching profession (*Elementary Praxis II*) in Missouri.

- 1) What impact does developmental and general education mathematics course work have on elementary teacher candidates' performance on the mathematics strand of the *CBASE*?
- 2) What impact does developmental and general education mathematics course work have on elementary teacher candidates' performance on the overall score of the *Elementary Praxis II*?
- 3) What impact does developmental and general education mathematics course work have on elementary teacher candidates' performance on the mathematics strand of the *Elementary Praxis II*?

Null Hypotheses

- 1) There will be no significant interaction effect between developmental and general education mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates.
- 2) There will be no significant main effect between developmental mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates.
- 3) There will be no significant main effect between general education mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates.
- 4) There will be no significant interaction effect between developmental and general education mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates.

- 5) There will be no significant main effect between developmental mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates.
- 6) There will be no significant main effect between general education mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates.
- 7) There will be no significant interaction effect between developmental and general education mathematics course work and the mathematics subtest scores on *Elementary Praxis II* of elementary teacher candidates.
- 8) There will be no significant main effect of developmental mathematics course work and the mathematics subtest scores on *Elementary Praxis II* of elementary teacher candidates.
- 9) There will be no significant main effect of general education mathematics course work and the mathematics subtest scores on *Elementary Praxis II* of elementary teacher candidates.

Research Hypotheses

- 1) There will be an interaction effect between developmental and general education mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates.
- 2) There will be a main effect between developmental mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates.
- 3) There will be a main effect between general education mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates.

- 4) There will be an interaction effect between developmental and general education mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates.
- 5) There will be a main effect between developmental mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates.
- 6) There will be a main effect between general education mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates.
- 7) There will be an interaction effect between developmental and general education mathematics course work and the mathematics subtest scores on *Elementary Praxis II* of elementary teacher candidates.
- 8) There will be a main effect of developmental mathematics course work and the mathematics subtest scores on *Elementary Praxis II* of elementary teacher candidates.
- 9) There will be a main effect of general education mathematics course work and the mathematics subtest scores on *Elementary Praxis II* of elementary teacher candidates.

Significance of the Study

This study is intended to further the body of research centering on the mathematical content preparation of elementary teacher candidates. The focus of this study is to investigate the impact the number of developmental mathematics courses and the level of algebraic integration in general education mathematics course completed has on elementary teacher candidates' performance on the subject content test and licensure test required in Missouri. To date, no studies have been found that categorize the mathematical course work completed or use these specific tests in this manner.

Various studies have utilized subject specific course work as a measure of the level of teachers' mathematical content knowledge. These studies tend to either not differentiate the different types of mathematics course work (Eberts & Stone, 1984; Hill, Rowan & Ball, 2005) or to simply classify them by mathematics versus mathematics education course work (Harris & Sass, 2007; Kukla-Acevedo, 2009). Most of the studies only take into account the number of courses completed (Eberts & Stone, 1984; Hill, Rowan, et al., 2005; Harris & Sass, 2007). However, some studies do exist that utilize the grades earned in those courses (Kukla-Acevedo, 2009). Studies involving using subject specific course work mainly focus on the impact this proxy has on student achievement as measured by scores students earned on a test taken (Eberts & Stone, 1984; Hill, Rowan, et al., 2005; Harris & Sass, 2007; Kukla-Acevedo, 2009).

As part of the No Child Left Behind Act of 2001 (NCLB), states were to have testing protocols in place to ensure individuals entering into the elementary school teaching profession possessed a sufficient knowledge base of the core subject taught at that level (U.S. Department of Education, 2004). This mandate promotes the belief that the most important indicator of subject knowledge proficiency for elementary school teachers is the ability to pass a licensure test. As a result, a line of inquiry examining what impact various mathematical attributes of elementary teacher candidates have on performance on both subject content and licensure tests would be beneficial.

One study was identified that falls within this line of inquiry (Capraro, Capraro, Parker, Kulm, Raulerson, 2005). This study investigated the impact grades elementary teacher candidates earned in core mathematics courses had on their scores on the content knowledge and pedagogical content knowledge portions on the licensure test *ExCET*. Capraro, et al.

(2005) found that a positive significant correlation existed between grades earned in core mathematics courses and the performance on both portions of the *ExCET*. Although this study provides valuable insight into the mathematical content preparation of elementary teacher candidates, it does not offer any information about the effect of developmental mathematics course work on elementary teacher candidates' test performance. In addition, it offers no information regarding the widely used *CBASE* and *Elementary Praxis II* tests.

Definition of Terms

College BASE (CBASE) – An academic achievement test focusing on English, mathematics, science, social studies and reasoning competency that students complete with the goal of obtaining a score for each content strand at or above the score necessary to be admitted into undergraduate teacher education programs in Missouri.

General education mathematics courses – Courses that are required by the institution of higher education used in this study for obtaining an undergraduate degree. These courses are also referred to as core mathematics or college-level mathematics courses.

Developmental mathematics courses – Courses that underprepared college students complete to obtain the pre-requisite skills for general education mathematics. These courses are also referred to as remedial mathematics courses.

Elementary Education Praxis II: Curriculum, Instruction & Assessment (Elementary Praxis II) – An assessment instrument focusing on the knowledge essential for teaching at the elementary school level that elementary teacher candidates complete with the goal of obtaining an overall score at or above the score necessary to acquire Missouri certification to teach at the elementary school level.

Pedagogical content knowledge – A term defined by Shulman (1986) as “the particular form of content knowledge that embodies the aspects of content most germane to its teachability” (p. 9).

Elementary teacher candidate – A student at an institute of higher education who is working to obtain an undergraduate degree designed to satisfy requirements for certification at the elementary school level. These students have traditionally been referred to as pre-service elementary teachers.

School mathematics – The scope and sequence of mathematics that forms the curriculum for elementary, middle and secondary levels of schooling.

Teacher training programs – Programs that serve the purpose of preparing individuals for careers in teaching at the elementary, middle and secondary levels of schooling.

Limitations of Study

There are five limitations of this study. First, the uniqueness of the university may hinder the ability to generalize this study. Traditionally, elementary teacher candidates at this university tend to be Caucasian females. Males and minorities are anticipated to be underrepresented. According to the Registration Office at the university under study, 97% of students who were awarded a degree in elementary education from 2003 to 2011 were females. Furthermore, 91% were Caucasian. As a result, effect of gender and race will not be considered. In addition, the results may be different if the university were a public instead of private institution of higher education.

Secondly, it is recommended that elementary teacher candidates attempt the *CBASE* upon completion of their content mathematics course sequence and the *Elementary Praxis II* upon completion of their mathematics methods courses. However, the written policy of the

education department of the under study university only states that the individual must obtain a passing score on each subtest of the *CBASE* before being admitted to the elementary education program and must obtain a passing overall score on the *Elementary Praxis II* before graduating from the program. As a result, teacher candidates may experience a longer time period between completing their undergraduate mathematics course work and the *CBASE* examination due to having completed the course work while in high school or applying for admissions into the teacher training program after their sophomore year. In addition, teacher candidates may have completed the *Elementary Praxis II* before completing the required mathematics methods courses. Since the timeline of course work and tests cannot be guaranteed, an increase in compounding variables may result.

Thirdly, use of the mathematics *Elementary Praxis II* score is the one predicted to provide the most information in regard to the impact of content course sequencing. However, until recently, those scores were not provided to the university from the provider of the test, Educational Testing Service (ETS), for all the teacher candidates who had completed the test. Also, ETS cautions that use of the subtests' scores may not be reliable. As a result, the first investigation will consider the effect on the overall *Elementary Praxis II* score and the second one will consider the effect on the mathematics strand *Elementary Praxis II* score.

Fourth, by nature, the design of the study is quasi-experimental. The grouping is dependent on the undergraduate mathematics course needs of the individuals. At the university under study, entering students who have not already completed their undergraduate mathematics course work elsewhere are placed into a course using their ACT, SAT or ACCUPLACER scores. Students placing in Introductory Algebra must complete Intermediate Algebra before enrolling in their general education mathematics course.

Furthermore, students who are majoring in education at the elementary level may choose to complete either College Algebra or Finite Math to satisfy their general education mathematics requirement.

Fifth, the researcher has no control over the level of instruction of the actual mathematics course work completed. That is, students were not required to take the course work at the institution of higher education used in this study. Since the developmental and general education mathematics courses are not required to be completed at the university under study, there was no means available to control for differences in the level of instruction or the teaching strategies used in these courses. However, instruction in entry-level mathematics courses is generally standardized across institutions. To illustrate, in 1995, Cohen put forth the challenge that “the role of the teacher must change from a sage who hands down knowledge to a coach who provides guidance and support” (p. 42). In addition, Cuban (2001b) observed:

Within this overall climate of heightened concern for preparing students for college and information-based workplace and increased emphasis on the newest technologies, mathematics and science teachers still lecture, require students to take notes, assign homework from tests, and give multiple-choice tests. (p. 90)

Furthermore, an analysis of the table of content of textbooks used in these courses at various institutes of higher education in the area was performed. The result of the analysis showed a consistency of core topics in these courses. Thus, in practice, the mathematics courses included in the present study tend to be taught in the same pedagogical way and to teach the same content.

CHAPTER 2

REVIEW OF THE RELATED LITERATURE

An in-depth look at the evidence, as described by the No Child Left Behind (NCLB) act, that demonstrates a mastery of the core academic subjects of the elementary school curriculum for elementary teacher candidates, provides the framework for this study. Assessing content knowledge of core academic subjects taught by early childhood and elementary teachers has challenges that are not present at the middle or secondary levels. According to NCLB, the core academic subjects are English, reading or language arts, mathematics, science, foreign language, civics and government, economics, arts, history, and geography (NCLB, 2002). Elementary teachers tend to major in education versus majoring in one or more of the core academic subjects as middle and secondary teachers commonly do. Likewise, licensure tests for elementary teachers are designed to assess their knowledge in a variety of the core academic subjects versus focusing on one.

The Highly Qualified Teacher (HQT) mandate of the NCLB requires all states provide the evidence that, before entering into the field, all elementary teacher candidates in the state have acquired the level of mastery of the core academic subjects of the elementary school curriculum required by law. However, it requires no uniformity among the states as to the course work to be completed to develop the knowledge base or the instruments used to assess the level of mastery. In addition, NCLB makes no mention of the amount of emphasis to place on pure content knowledge versus pedagogical content knowledge.

Towards the end of the 1970s, the Conference Board of the Mathematical Sciences (CBMS) released a report created by their National Advisory Committee on Mathematical Education that

shed light on the “Back to the Basics” movement that was occurring at that time (CBMS, 1975). In the document, the CBMS criticized the movement as being too focused on the computational aspects of mathematics. They called for a broader view that included problem solving with real world applications and improving students’ ability to interpret data.

Within two years after the release of the report, the National Council of Teachers of Mathematics (NCTM) published their position statement on basic skills in support of the changes recommended by CBMS (NCTM, 1977). As a result, the NCTM began promoting a new perspective of balance between content and pedagogy (Fey & Graeber, 2003). Over the last twenty years, this perspective has gained momentum. This new trend has resulted in the need for elementary teacher candidates to acquire a diverse knowledge base of mathematics. Within this review of literature, the following four areas will be examined: (1) P-12 student achievement in mathematics as it is related to their in-service teachers’ content knowledge, (2) foundations of the mathematical training of elementary teachers in the United States, (3) presenting, developing and assessing mathematical subject content knowledge, and (4) testing of elementary teacher candidates in the United States.

*P – 12 Student Achievement in Mathematics and Their
In-Service Teachers’ Content Knowledge*

To understand mathematics, students need to continually observe the interconnectedness of mathematical ideas (NCTM, 2000). Experts in the field strive to determine the scope and sequence for P-12 school mathematics most effective in supporting student learning. A well-designed curriculum alone is not sufficient for building a solid foundation in mathematics (MA, 1999). Teachers who are responsible for implementing the curriculum serve a critical

role (NCTM, 2000). They are the primary decision makers regarding the instructional strategies to be used in the classroom and the amount of emphasis placed on the importance of each topic in the curriculum as a whole.

Several factors suggest a direct correlation between mathematics achievement of students and their teachers' knowledge base. As mathematical concepts transition from basic to more advanced, the reliance on the teacher for the transfer of knowledge increases (National Research Council, 2001a). Furthermore, students tend to lack the innate ability to relate the mathematics seen outside the classroom to the mathematics experienced inside the classroom (National Research Council, 2005). Stodolsky, Salk and Glaessner (1991) found a significantly smaller number of fifth-graders who believed they were capable of learning mathematics independently than learning social studies in the same manner, $\chi^2(2, N = 60) = 13.025, p < .01$.

In 2006, the National Mathematics Advisory Panel (NMAP) was created by Executive Order 13398 with the purpose of using "the best available scientific research to advise on improvements in the mathematics education of the nation's children" (NMAP, 2008a, p. xv). The impact in-service teachers' knowledge of mathematics has on student achievement was one of many lines of inquiry of the NMAP. The Teachers and Teacher Education Task Group of the NMAP determined teachers' course work completed and test performance to be valid estimators of teachers' mathematical content knowledge.

For course work, the Task Group included studies that examined the effect of course work emphasizing content as well as course work emphasizing pedagogy. Overall, the results of these studies were mixed. Among the five studies examining the effect of teachers' course work on student achievement in mathematics, only two concluded no significant

relationship existed (Eisenberg, 1977; Hill, Rowan & Ball, 2005). Of the three studies that did indicate a significant relationship, the results suggested the relationship existed only for students in tenth grade or above (Monk, 1994; Monk & King, 1994; Harris & Sass, 2007). The results of these studies support the continual monitoring of the mathematics courses required for certification in mathematics at the secondary level. In addition, the results of all five studies together suggest a need to question if the mathematics courses required for certification at the elementary level build the mathematical foundation necessary for increasing student achievement in mathematics.

For test scores, the Task Group examined studies that centered on the effect of teachers' performance on commonly used standardized tests, tests mandated by governmental departments of education or tests employed specifically for the study. Of the seven studies considered by the Task Group, five concluded a significant relationship existed (Clotfelter, Ladd, & Vigdor, 2007; Harbison & Hanushek, 1992; Hill, Rowan & Ball, 2005; Mullens, Murnane, & Willett, 1996; Sheehan & Marcus, 1978). Of the two studies that concluded the relationship was not significant, only one found a negative relationship (Harris & Sass, 2007). These results indicate the existence of a predominately positive relationship between teachers' test scores and student achievement in mathematics (NMAP, 2008b).

The findings of the Teachers and Teacher Education Task Group warrant further exploration of measuring in-service teachers' mathematical content knowledge by teachers' course work and test scores. This exploration will mainly focus on studies that were identified in the final report from the Task Group. Due to the thoroughness of their work, only a few additional studies were identified that investigated the impact teachers' course work completed or test score earned had on student achievement. Unless otherwise stated, in

this section *teachers' content knowledge* refers to *in-service teachers' knowledge of mathematics* and *achievement* refers to *P-12 student achievement in mathematics*.

Over the last forty years, the descriptors researchers have used to quantify the mathematics course work completed have ranged from only considering the number of courses completed to using the performance in those courses to measure the level of understanding. Using the number of mathematics courses teachers completed above calculus, Eisenberg (1977) reported no statistically significant correlation between junior high school student achievement in algebra and teachers' content knowledge, $r(23) = -0.25$. Ebert and Stone (1984) reached the same conclusion when studying the impact any college level mathematics course teachers completed within the last three years had on the achievement of fourth-graders, standardized $\beta = .004$, $t = 0.74$, df not reported, $n = 14,882$.

During the early 1990s, two analyses using different approaches for incorporating the mathematics course work completed by teachers were performed on essentially the same group of students. Data collection started when the students were in their sophomore year and continued into their junior and senior years. In the first analysis, Monk (1994) separated the number of courses completed by teachers into the four categories: undergraduate mathematics, graduate mathematics, undergraduate mathematics education and graduate mathematics education. The impact of teachers' undergraduate mathematics education course work on achievement during the students' sophomore year was determined to be statistically significant using traditional levels of significance, $\beta = 0.29$, $p < .01$, $n = 608$. When increasing to a .10 level of significance, the impact of teachers' undergraduate mathematics course work on achievement of the same group of students was also found to be statistically significant, $\beta = 0.08$, $n = 608$. The impact of teachers' undergraduate mathematics course

work on achievement during the students' junior year was determined to be statistically significant using traditional levels of significance, $\beta = 0.77$, $p < .01$, $n = 608$. At a higher level of significance, the impact of teachers' undergraduate mathematics education course work on achievement during the students' junior year was also determined to be statistically significant, $\beta = 0.27$, $p < .05$, $n = 608$.

In the second analysis, Monk and King (1994) used the single variable of teacher preparation to represent the total number of undergraduate and graduate mathematics courses completed. In addition, the focus appeared to be on mathematics content course work with no mention of mathematics education course work. For the majority of models considered by the researchers, teacher preparation was shown to be positively but not necessarily significantly related to achievement. Using traditional levels of significance, the only significant relationship existed between teachers' course work and achievement of sophomores who had high pre-test scores at the beginning of their sophomore year, $\beta = 0.06$, $p < .05$, $n = 1,028$. When increasing to a .10 level of significance, the relationship between teachers' course work and achievement of all sophomores became significant, $\beta = 0.04$, $n = 1,955$. No significant relationships between teachers' course work and achievement of students in their junior year were found, $\beta = 0.00$, $n = 1175$. Thus, teachers' course work completed had the greatest effect on achievement of students who earned high scores on the pre-test given at the beginning of their sophomore year. This relationship did not continue into the students' junior year.

During the 2000s, researchers continued to use a variety of philosophies for defining mathematics course work taken by teachers to gain more insight into its impact on achievement. Hill, Rowan and Ball (2005) instructed the first- and third-grade teachers to

report the number of mathematics content courses and mathematics methods courses completed separately. However, due to issues with multicollinearity, the researchers were forced to combine the two values into one single variable. For first-graders, course work completed by teachers was shown to have a positive but not significant relationship with achievement, $\beta = 0.55$, $n = 334$. For third-graders, course work completed by teachers was also shown to have a positive but not significant relationship with achievement, $\beta = 1.70$, $n = 365$.

In their study, Harris and Sass (2007) utilized a data set that differentiated the mathematics course work completed as (1) pedagogical-content credits, (2) subject-content credits, (3) mathematics credits and (4) statistics credits. The pedagogical-content credits and subject-content credits math courses are taught by faculty members of the education department. Both courses include math content but only the pedagogical-content credits courses also include pedagogy. In addition, their data allowed them to consider the correlations between course work completed by teachers and achievement at the elementary, middle and secondary levels of schooling. At the elementary school level, three of the four correlations were found to be negative. The only positive correlation was not significant. At both the middle and secondary school levels, three of the four correlations were positive with the majority of them found to be not significant. The only correlation shown to be positive and significant was between subject-content credits and achievement for students at the secondary level, $\beta = 3.60$, $t = 2.31$, df not reported, $p < .05$, $n = 4,487$. These results suggest increase in student achievement at the secondary level is influenced more by differences in the mathematical training of teachers than in students at both the elementary and middle levels. The smaller number of positive correlations for the elementary level versus the middle

and secondary levels indicates a need for more insight regarding the course work completed by elementary teachers.

Kukla-Acevedo (2009) added the dimension of GPA for both math and math education hours completed. Thus, the four variables representing course work were math hours, math GPA, math education hours and math education GPA. This researcher investigated the impact the interaction of each of the four variables representing mathematics course work completed and teachers' years of experience had on the achievement of fifth-graders. In her study, Kukla-Acevedo (2009) revealed that teachers' number of math education hours predicted student achievement, $\beta = 0.39$, $p < .01$, $n = 1,988$. However, the impact of math education hours was negative until the tenth to fourteenth year in the profession. In addition, the impact of teachers' math content hours on student achievement was shown to be significant and consistently positive, $\beta = 0.28$, $p < .01$, $n = 1,988$. According to this study, teachers who have more math content hours will continue, for the duration of their career, to have students with achievement greater than students having teachers with fewer math hours.

Measuring the mathematics content knowledge of teachers by their performance on either a single test or a set of tests appears to be a more common practice in research than using mathematical course work completed. Several reasons may contribute to this occurrence. The requirements of Departments of Education at both the state and federal levels for incoming teachers tend to promote the use of test scores. The process for collecting test scores is more efficient than one for collecting mathematics course work completed by teachers over a period of four years or more. Determining the ability of a test to meet a set of criteria is often easier than determining the ability of a diverse list of courses completed. Further

complicating the matter, courses with the same title at different institutions may contain content that is considerably different.

Test performance used in studying the effect of teachers' content knowledge on student achievement can be grouped into three different phases. The first phase involves the test performance during or at the end of the teachers' own P-12 schooling. The second phase involves teachers' performance on licensure tests required for certification. The third phase involves teachers' performance on tests completed during their teaching career.

The literature for the first phase of test performance as a measure of teachers' content knowledge consists of three studies that illustrate the contrast between teacher training in Belize and in the United States. In theory, individuals interested in teaching in Belize complete a 3-year training program after they graduate from high school. Mullens, Murnan, and Willett (1996) revealed that approximately twenty-five percent of teachers teaching at the primary level of education had only completed a primary level themselves. Thus, in their study of the achievement of third graders in Belize, they utilized the scores from the Belize National Selections Examination (BNSE) earned during the teachers' own eighth grade year of schooling. Mullens, Murnan and Willett (1996) concluded that a significant positive relationship did exist between the teachers' mathematics ability and student achievement, $\beta = 3.64, p < .001, n = 49$.

At the end of P-12 schooling, students in the United States usually complete either the American College Testing assessment (ACT) or the Scholastic Achievement Test (SAT). Ferguson and Ladd (1996) studied the impact teachers' ACT scores had on the achievement of fourth- and eighth-graders in the state of Alabama. The researchers concluded that the impact was significant on achievement for eighth-graders, $\beta = 0.22, t = 3.19, df$ not reported,

$p < .05$, n not reported, but not for fourth-graders, $\beta = 0.06$, $t = 0.85$, df not reported, $n = 29,544$. Harris and Sass (2007) used teachers' individual SAT-equivalent entrance exam scores to quantify teachers' content knowledge, thus, expanding on their investigation involving the impact teachers' course work completed had on student achievement discussed previously. At the elementary school level, they found an association that was not significant, $\beta = 0.00$, $t = -0.45$, df not reported, $n = 1,380$. They found similar results at both the middle, $\beta = 0.00$, $t = -0.75$, df not reported, $n = 1,016$, and high school, $\beta = 0.00$, $t = -0.26$, df not reported, $n = 492$, levels. The different impact Belize teachers' test scores and U.S. teachers' test scores were found to have on student achievement indicates that using tests from U.S. teacher candidates' P – 12 schooling other than the ACT or SAT would provide more insight. However, since individual states in the U.S. select the tests used in P – 12, it would be difficult to compare the test scores.

The literature for the second phase of test performance as a measure of teachers' content knowledge consists of studies identified as having examined the impact of licensure test scores on student achievement. These studies all used the tests provided by Educational Testing Services (ETS). Starting in the 1940s, the ETS licensure test series was titled the National Teachers Examination (NTE). In the early 1990s, it was revised and renamed as the *Praxis* series of tests. To compensate for the variation of the tests, the test scores from different administrations of the test were normalized. If more than one test score for licensure was included in the file, the normalized test scores tended to be averaged to create a single value.

Sheehan and Marcus (1978) investigated the relationship between teachers' licensure test scores and first-graders' achievement. In their study, the researchers used the Weighted

Common Examinations Total (WCET), a combination of scores from the Professional Education and General Education tests of the National Teacher Examinations (NTE). Their results indicated that teachers' WCET scores did significantly predict student achievement, $F(1, 114) = 4.04, p < .05$.

In addition to the commonality of using the ETS licensure test series, many recent studies considering the effect of teachers' licensure test scores on student achievement centered on school districts in North Carolina. The primary reason for this occurrence is that the administrative records housed in the North Carolina Educational Research Data Center (NCERDC) provide researchers the rare ability to link P-12 students to specific teachers (Goldhaber, 2007). Strauss and Sawyer (1986) concluded that teachers' NTE score had only a slight impact on the achievement of eleventh-graders in North Carolina, $\beta = 0.71, t = 3.52, df$ not reported, $n = 105$. However, when the researchers shifted their focus from achievement to rate of mathematics failures, they found a 1% increase in teachers' NTE score resulted in a 5% decrease in failures (Strauss & Sawyer, 1986).

Clotfelter, Ladd and Vigdor (2006) initially focused their attention on North Carolina students enrolled in the fifth grade during the 2000 – 2001 academic year. They concluded that the teachers' licensure test score had a positive significant impact on the achievement of fifth-graders, $\beta = 0.02, p < .01, n = 60,656$. In a second study, the researchers enlarged their sample to include the third-, fourth- and fifth- grade mathematics achievement for all North Carolina students from 1995 to 2004. Clotfelter, Ladd and Vigdor (2007) found that teachers' licensure test scores had a positive significant impact on the achievement of students in third-, fourth- and fifth-grades $\beta = 0.01, p < .01, n$ not reported.

Using relatively the same data set as in the longitudinal study of Clotfelter, et al., Goldhaber (2007) also examined the impact teachers' licensure test scores had on third-, fourth- and fifth-graders' achievement. When Goldhaber calculated teachers' licensure test scores in the same manner as the study performed by Clotfelter, et al., his results supported their conclusion, $\beta = 0.06$, $p < .01$, $n = 174,589$. In addition, Goldhaber broadened the examination to consider teachers' *Praxis II* scores in relation to the *Praxis II* cut scores of North Carolina before 2000, of North Carolina starting in 2000 and of Connecticut at the time of the study. Starting in 2000, North Carolina shifted from having separate cut score requirements for the Curriculum and Content subsections of the *Praxis II* test to having one combined cut score requirement. At the time of the study, Connecticut had cut score requirements for the two subsections of the *Praxis II* that were higher than those of North Carolina before 2000. Goldhaber (2007) found students of teachers who had met North Carolina's 1997 cut score requirements did have achievement significantly higher than those of teachers who did not meet the requirements, $\beta = 0.07$, $p < .01$, $n = 174,589$. This relationship remained for students of teachers who had met North Carolina's 2000 cut score requirements, $\beta = 0.06$, $p < .01$, $n = 174,589$. When Goldhaber changed the criteria to meeting the higher Connecticut cut scores, the shift in cut scores did not produce a significant change in the results from the ones acquired using the lower North Carolina cut scores, $\beta = 0.01$, $n = 174,589$.

The literature for the third phase of test performance as a measure of teachers' content knowledge consists of studies identified as having examined the impact of scores teachers earn on a test taken during their teaching careers on student achievement. Few studies of this nature exist since administering tests to in-service teachers is not a common practice in

research. As a result, studies in the third phase, unlike the first and second phases, lacked the availability of widely used standardized tests to measure the content knowledge of the teachers. Thus, the tests completed by the teachers varied from study to study.

In a study of second- and fourth-graders' achievement in Brazil (Harbinson & Hanushek, 1992), teachers completed the same test taken by the fourth-graders. The average of the fourth-grade teachers' scores was 87.3, which was a value lower than expected (Harbinson & Hanushek, 1992). The results for second-graders indicated a significant relationship between teachers' content knowledge and student achievement, $\beta = 0.12$, $p < .05$, n not reported. Furthermore, the results for fourth-graders indicated a significant relationship between teachers' content knowledge and student achievement, $\beta = 0.52$, $p < .05$, n not reported.

In his study, Eisenberg measured teachers' content knowledge using "a 50-minute multiple-choice test of 34 questions designed to measure the teacher's understanding of the real number system and other related algebraic structure" (Eisenberg, 1977, p. 217). This test had been used in a previous study by Begle (Eisenberg, 1977). The teachers included in this study taught algebra at the junior high school level. Eisenberg (1977) found no significant correlation between teachers' score and student achievement, $r = -.18$, $n = 25$.

Rowan, Chiang and Miller (1997) utilized data collected from the National Education Longitudinal Study of 1988 (NELS:88). This survey tracked students across the United States from eighth-grade until tenth-grade. As part of NELS:88, teachers completed a one-item mathematics quiz. The quiz item presented a question and several students' responses to the question with only one being correct. The teachers were to select the response that was correct. Rowan, et al. (1997) concluded that students who, during their tenth-grade year, had

teachers who answered the quiz item correctly did perform slightly better on the tenth-grade NELS mathematics test, $\beta = 0.02$, $t = 2.43$, df not reported, $p < .05$, $n = 5,381$.

In the study of Hill, Rowan and Ball (2005), first- and third-grade teachers completed a test developed by Hill, Shillings and Ball. This instrument, referred to as the CKT-M, consisted of 30 items designed to measure both knowledge of the subject itself and knowledge used in the teaching of the subject. To ensure an appropriate level of quality, a draft was created using test items submitted by experts in the field and then piloted in California's Mathematics Professional Development Institutes. In their study, Hill, et al. (2005) found that a positive significant relationship existed between teachers' test performance and student achievement of first-graders, $\beta = 2.12$, $p < .05$, $n = 334$. In addition, they found the relation remained when examining the student achievement of third-graders, $\beta = 1.96$, $p < .01$, $n = 365$.

The literature considered in this section provides justification for investigating the impact elementary teacher candidates' course work has on their licensure test performance. Four of the studies found at least one significant relationship existed between teachers' course work and student achievement (Harris & Sass, 2007; Kukla-Acevedo, 2009; Monk, 1994; Monk & King, 1994). However, only one of those studies examined student achievement at the elementary school level (Kukla-Acevedo, 2009). Eight of the studies found a significant relationship existed between teachers' test performance and student achievement (Ferguson, 1996; Clotfelter, Ladd & Vigdor, 2006; Clotfelter, Ladd & Vigdor, 2007; Goldhaber, 2007; Harbison & Hanushek, 1992; Hill et al, 2005, Mullens, Murnane & Willett, 1996; Sheehan & Marcus, 1978). Seven of those eight studies examined student achievement at the elementary school level. In addition, four of those seven studies used licensure test performance as the

instrument for measuring teachers' content knowledge. From this literature, a theme that appears to emerge is that teachers' licensure test performance is a better indicator of elementary students' mathematical achievement than teachers' mathematics course work completed. As a result, university teacher training programs would benefit from investigations into how elementary teacher candidates' mathematics course work influence licensure test scores.

*Foundations of the Mathematical Training of Elementary
Teachers in the United States*

The mathematical training of elementary teacher candidates in United States is one component of the intricate system of teacher training. As a result, development of the overall system of teacher training will be discussed as it relates to the mathematical training of elementary teacher candidates. Several works written during the early 1900s provide insight into the mathematics course work required to be completed by elementary teacher candidates during that period. The major shift that occurred in teacher training after World War II and its impact on the mathematics course work required to be completed by elementary teacher candidates will be examined. This section will focus on the mathematics course work specifically designed for the elementary teacher candidates. Mathematics course work for the general population of college students will be mentioned in this section but discussed in-depth in the next section.

The first formal institution developed in the United States with the purpose of training teachers was in the form of privately operated seminaries. Reverend Samuel R. Hall is credited with starting this movement in the United States by opening the first seminary in Vermont during 1823 (Cubberley, 1919; Learned, Bagley, McMurray, Strayer, Dearborn,

Kandel & Josselyn, 1920). In addition, by publishing a compilation of his lectures in a book titled *Lectures to Female Teachers on School-Keeping*, he became the first U.S. author to write a book regarding the profession of education (Cubberley, 1919; Learned et al., 1920). Even though the majority of the book is devoted to the management of the overall school, he does make reference to the knowledge of arithmetic needed by primary teachers and the “Art of Teaching” it (Cubberley, 1919). In regards to the mathematical subject content knowledge, he wrote,

Arithmetick (*sic*) should be familiar to primary instructors (*sic*). Intellectual arithmetick is a proper, and highly important study for children. . . . And certainly no one is prepared to act as a successful instructress, without a thorough acquaintance, with the science of numbers, at least so far as taught in Mr. Colburn’s “First Lessons.” It is not sufficient to \ be able to ascertain the answer, in a given instance; but the whole process of reasoning on every sum, should be as familiar as a rule in syntax, or a definition in geography. (Hall, 1832, p. 79)

In regards to the mathematical pedagogical content knowledge, he wrote,

Take the numeral frame or arithmeticon, or, if not possessed of either of these, take pieces of paper, or anything else which may be seen by all the children at the same time, and point to one at a time, let them count – then change the exercise and count by two and three, &c. As another exercise they may be taught to add two to two, to four, to five, &c. continuing as far as they are able. Then add three to three, to four, &c. (Hall, 1832, p. 132-133)

States’ active involvement in teacher training began in New York. A law passed in 1834 mandated the funding of common school teacher training programs in eight academies across the state of New York (Cubberley, 1919). These programs tended to focus mainly on the content knowledge of each subject of the common schools’ curriculum with very little regard to the pedagogical content knowledge (Cubberley, 1919). Several states passed similar legislation for the funding of teacher training programs in their academies.

Starting in the 1820s, a new type of institution for training teachers, referred to as normal schools or colleges, began to emerge (Learned et al., 1920). The first institute of this type in

the United States was established in Vermont in 1823 (Morris & Morris, 1977). However, the founding of the first state normal school in Massachusetts in 1839 is typically credited with the start of the movement within the United States (Learned et al., 1920; “Teaching”, 2007). In Massachusetts during the 1840s, individuals interested in attending needed to indicate a desire to teach, pass an examination of common school subjects and be at least 17 years of age if male and 16 if female (Learned et al., 1920). A secondary education was not a requirement for admission into normal schools of this period.

Normal schools offered educational opportunities at a low cost to females and minorities not available elsewhere (Ogren, 2005). Due to low admission standards, courses in liberal arts subjects were a necessary part of the normal school curriculum (Ogren, 2005). At normal schools, students could choose between certification that allowed for only teaching at the primary level or an advanced one that allowed for teaching at higher levels (“Teaching”, 2007).

A study of tax-supported normal schools in the state of Missouri provides insight into the training of primary school teachers in that state during the early 1900s. In the early stages of normal schools in Missouri, the normal schools in St. Louis and Kansas City were renamed as city training schools (Learned et al., 1920). Admission to these city schools required a full secondary education (Learned et al., 1920). To earn a certification for teaching in the elementary school from both normal schools and city training schools, students were required to complete a 60-hour curriculum (Learned et al., 1920).

The difference in the function of the normal school and that of the city training school are reflected in the specific subject course work required for graduation from the respective institutions. In theory, the primary mission of both types of institutions was to train teachers.

In reality, many students enrolled in normal schools viewed training to teach at the elementary school level as the first step to teaching at the high school level, to earning an administrative position or for enrollment into institutions of higher education (Learned et al., 1920). Therefore, to meet the needs of their students, normal schools designed students' curriculum plans around their individual needs which did not always include courses that developed the knowledge needed for teaching at the elementary school level. As a result, students were allowed to select subject matter course work from a group of courses (Learned et al., 1920). For example, lists of individual course work completed by students who earned the 60-hour diploma provided in the study of Missouri normal schools showed only four out of six students completed a course in the teaching of arithmetic (Learned et al., 1920). Two out of the four students completed additional course work in mathematics. The two students who did not take a course in the teaching of arithmetic completed courses in higher levels of mathematics as part of their 60-hour diploma. Thus, these students were given the flexibility to choose a course in arithmetic, algebra, geometry and trigonometry to satisfy the requirements for a 60-hour diploma.

Unlike the students in the normal schools, students at the city training schools viewed obtaining a teaching position in city elementary schools as a lucrative position and not a step towards something better (Learned et al., 1920). Therefore, students enrolled in the city training schools with the single desire of teaching at the elementary school level. As a result, students of these schools were required to complete a prescribed list of courses. For example, students of the city training school in St. Louis completed five semester hours of arithmetic their first semester and one-half hour during their fourth semester (Learned et al., 1920).

Students of the Kansas City training school completed three semester hours of arithmetic during both their third and fourth semesters.

In his study, Lee (1928) investigated the attitudes students of the New York's Jamaica Training School held towards the academic subjects they were studying. His results indicated seventeen percent of the students found arithmetic to be an "easy" subject. The only subject that had a higher percentage was psychology, which received nineteen percent. Furthermore, sixty percent of the students indicated their "favorable liking for the teacher" (Lee, 1928, p. 234) as the main reason for their rating of each subject. Eleven percent of the students found arithmetic to be a "difficult" subject (Lee, 1928). The only subject that had a higher percentage was music which received eighteen percent. Furthermore, fifty-nine percent of the students indicated their "lack of ability to get along in the subject" (Lee, 1928, p. 236) as the main reason for their rating of each subject. Thus, these results suggest that the attitudes of the students in this training school towards the level of difficulty of arithmetic were more teacher and ability dependent than the majority of other subjects of the training school.

In the late 1880s, universities began offering programs designed to train individuals interested in teaching at the elementary school level. The establishment of Columbia Teachers College in 1888 is credited with greatly influencing this movement (Morris & Morris, 1977). The admission standards and curriculum of Columbia Teachers College appear to be similar to those of the city training schools of Missouri. Entering students were required to have completed a full secondary education ("Teaching", 2007). To earn a certification in teaching from either of these institutions, students completed a set of specific concurrent courses ("Teaching", 2007). One of the main differences between city training

schools and Columbia Teachers College was that the former only offered certification at the elementary school level, whereas, the latter offered training in various levels of teaching.

Historically, the aim of both the normal schools and teacher colleges was to equip teachers to teach within the classrooms of the time period. However, in its 1901 statement of purpose, Columbia Teachers College acknowledged the need for teachers to be trained not only in the practical aspects of teaching but also in the theoretical ones (“Teaching”, 2007). Two texts regarding teaching of arithmetic from the early 1900s illustrate the difference in the two aspects of teaching. The first text was written by James Robert Overman, the Head of the Mathematics Department of the Ohio State Normal College located in Bowling Green (Overman, 1920). The second text was written by David Eugene Smith, a Professor of Mathematics at Columbia Teachers College (Smith, 1913).

In his book, Overman (1920) appeared to show a narrower view of the teaching of arithmetic than Smith (1913) did in his text. For example, Overman’s text consisted mainly of instructional materials that he had developed himself. Smith integrated the works of notable individuals such as Pestalozzi, Tillich, Grube and Montessori (Smith, 1913). In addition, Overman provided copies, descriptions and student results of common standardized tests administered to primary level students during the early 1900s. Smith made no mention of these tests. However, Smith (1913) devoted a chapter to suggestions for experimentation regarding the teaching of arithmetic. Overman devoted no pages to this endeavor. These examples demonstrate the different approaches in the training to teach arithmetic at an Ohio State Normal College versus Columbia Teachers College.

By the end of the 1900s, institutes created for the purpose of training teachers were no longer separate from the university system. The first phase occurred between 1910 and 1940

when state normal schools transitioned to state teachers or liberal arts colleges (Ducharme & Ducharme, 2003; Ogren, 2005). The second phase occurred during the 1960s and 1970s when state teachers colleges merged with state universities (Ducharme & Ducharme, 2003).

At the beginning of the movement away from teachers colleges, James Bryant Conant, a former president of Harvard, performed a comparison of twenty liberal arts colleges he referred to as prestigious and ten teachers colleges (Conant, 1963). His main focus was on the general academic requirements of these institutions. When considering the mathematics requirements, he found seven of the teachers colleges but only three of the liberal arts colleges had a requirement specifically in the subject. After an analysis of several other general requirements, Conant (1963) claimed:

I have taken time to discuss the diversity in general requirements among our colleges simply to show the folly in assuming that because a young man or woman holds a bachelor's degree from a so-called liberal arts college or a university he will necessarily have greater "breadth" in his educational background than a graduate of a teachers college. (p. 90)

Structuring a teacher training program that would best suit the needs of the students caused conflict among the leaders and faculty members of the university systems (Conant, 1963). The commonly held belief within universities was that educational course work was vocational in nature and, therefore, was secondary to course work in the academic subjects (Conant, 1963). As a result, state laws were created to ensure proper attention was given to the pedagogical training necessary for teaching (Conant, 1963).

In 1999, the American Council on Education (ACE) clarified the importance of higher education in the cycle of education in an address to college and university presidents. "For if the teachers we prepare are less prepared than they should be and the schools fail, colleges and universities will be drained of their very life-blood, well prepared entering college

students” (ACE, 1999, p. 4). Within this message is a call to action for university leaders to investigate the effectiveness of various elements of the teaching training programs at their own institutions since they are a stake holder of their own product.

During the 2000s, the CBMS produced two reports, commonly referred to as the MET I and the MET II, centering on the mathematical training of teachers (CBMS 2001, CBMS, 2012). Included in these reports were recommendations designed to guide universities in their decision- making efforts in future restructuring of mathematics programs for teacher candidates. Both reports made specific recommendations for elementary, middle and secondary teacher candidates.

The recommended number of semester hours for elementary teacher candidates to develop the knowledge base needed for teaching mathematics was 9 in MET I and 12 MET II (CBMS 2001; CBMS 2012) in addition to any general education mathematics course work universities will often require of their general population of students. Furthermore, provided in the MET II is a call to mathematicians and university leaders to recognize the importance of providing quality courses designed specifically for developing the knowledge base needed to teach mathematics at the elementary school level.

In 2009, the U.S. Department of Education (USDOE) published the results of a study comparing the implementation of the NCLB’s teacher quality requirement among all 50 states. According to the report, elementary teachers who were identified as highly qualified indicated completing on average 4.4 college mathematics courses. Furthermore, elementary teachers who were identified as not highly qualified indicated completing on average only 2.7 college mathematics courses. On the surface it appears that nationally both highly qualified and not highly qualified elementary teachers are completing close to or slightly

below the 12 credit hours recommended by MET II. However, the lack of knowledge of the type of mathematics course and the number of credit hours per individual course completed hinders the ability to make any firm conclusions.

Two articles published towards the end of the 1980s formalized important concepts pertaining to the training of teacher candidates. In the first article, Shulman (1986) coined the term pedagogical content knowledge (PCK) to mean understanding the techniques needed for teaching different subject matter. For example, PCK is the ability to develop an idea using a variety of strategies. In the second article, Buchmann (1987) applied the sociology term of folkways to teaching. Folkways, in relation to teaching, refers to teachers subconsciously imitating their past teachers' teaching strategies. According to Buchmann (1987), one of the greatest contributors to the reliance on lectures and recitations in the classroom is the presence of folkways in teaching.

Mathematics methods courses provide opportunities for teacher candidates to begin developing the pedagogical knowledge needed for teaching mathematics and to observe teaching techniques often different than ones they had experienced as students (Ball, 1989). Typically, teacher candidates enter their methods course with a preconceived portrait of themselves as a mathematics teacher (Ball, 1989). This image can be a source of inspiration or anxiety, depending on each teacher candidates' past experiences with mathematics. As teacher candidates progress through their methods courses, they engage in activities designed to guide them in revising their initial image to one that demonstrates the attributes necessary to effectively teach mathematics. For teacher candidates to disregard the numerous teachers they have encountered who mainly teach by lecturing, it is essential for methods courses to increase their confidence in implementing the revised image (Ball, 1989).

A body of literature exists that examines the impact mathematics methods courses have on elementary teacher candidates' attitudes towards mathematics. Clift and Brady (2005) identified twelve studies published from 1995 to 2002 that investigated the effect methods courses had on various elementary teacher candidates' mathematical attributes. The statistical evidence for the findings of the studies included in the document was not provided. Eleven out of the twelve studies examined the change in beliefs regarding the learning and teaching of mathematics. Nine of the eleven studies found a positive impact with only one stated as being significant (as cited in Clift & Brady, 2005). One of the twelve studies investigated the effect methods courses had on math anxiety. The findings indicated participation in the methods courses did decrease math anxiety, however, the level of significance was not provided (as cited in Clift & Brady, 2005). Furthermore, Graham (2007), a study not included in the report, concluded methods courses significantly reduced levels of mathematics anxiety experienced by groups that consisted of a combination of early childhood and elementary teacher candidates, $t(40) = 26.75, p < .05$.

A less common practice in research appears to be investigating the impact of these methods courses on the pedagogical content knowledge (PCK) of elementary teacher candidates. An exploration of literature revealed only three studies. One of the studies compared the test performance of a cohort of elementary teacher candidates who experienced either a piloted or a traditional type of methods course (McDevitt, Troyer, Ambrosio, Heikkinen & Warren, 1995). The content of both courses consisted of numeration, elementary set theory, problem solving, number theory, and the development of the systems of sets of numbers. Each member of the cohort in the two piloted methods courses completed, over two semesters, a total of nine courses together as a group. Teaching

strategies of the piloted methods courses were more inquiry-based than those of the other methods courses. Tests used to measure knowledge of manipulatives, everyday uses of mathematics and objectives commonly used to classify classroom activities were developed by project staff and instructors of the courses. McDevitt, et al. (1995) found elementary teacher candidates in the piloted methods courses did perform significantly better on the instrument designed to measure their knowledge of manipulatives, $t(74) = 5.42, p < .001$, and the one that measured their knowledge of everyday uses of mathematics, $F(1, 59) = 16.15, p < .01$. In addition, the cohort in the piloted methods courses did perform significantly better on one of the two components of the lesson plan evaluation instrument, $F(1, 89) = 5.80, p < .01$.

The two other studies examined the impact of methods courses on PCK of elementary teacher candidates compared from the beginning of the course test performance to the end of the course performance. Using the Essential Elements of Elementary School Mathematics Test developed by White, Quinn (1997) examined the change in meaningful mathematical knowledge of pre-service teachers. The results indicated that the meaningful mathematical content knowledge (MCK) of pre-service elementary teachers did increase at a significant level as a result of completing a methods course, $t(26) = 4.1, p < .001$. To measure mathematics content knowledge, Newton, Leonard, Evans and Eastburn (2012) selected a sample of 20 questions from the *Praxis* teacher examination to serve as both the pre- and post- test. Like Quinn, they found a statistically significant increase, $t(44) = -2.50, p < .05$. However, unlike Quinn, the resulting amount of increase was small.

Presenting, Developing and Assessing Mathematical Subject Knowledge

As part of earning a bachelor degree, elementary teacher candidates are often required to complete mathematics courses that do not appear to be directly related to their future profession (Floden & Meniketti, 2009). According to the Conference Board of the Mathematical Science's (CBMS) 2010 survey of undergraduate programs in the mathematical sciences in the United States, the mathematics courses for the general population of college students include precollege courses, liberal arts mathematics, college algebra, precalculus and trigonometry (Blair, Kirkman & Maxwell, 2013). This literature review will focus on college algebra, precollege mathematics and liberal arts mathematics.

When colleges were first being formed in the United States, mathematics was not studied by the general population of college students (Overn, 1937). Requiring students to enter college with some knowledge of arithmetic didn't occur until the mid-eighteenth century (Overn, 1937). In 1820, Harvard University became the first institute of higher learning to require their students to study algebra (Overn, 1937). By 1890, a textbook titled *College Algebra* was included in the Wells's Series of Mathematics offerings (Wells, 1890). According to Packer (2002), the following represents a typical college algebra course description:

This course is a modern introduction to the nature of mathematics as a logical system. The structure of the number system is developed axiomatically and extended by logical reasoning to cover essential algebraic topics: algebraic expression, functions, and theory of equations. (p. 1)

The evolution of the precollege mathematics course offerings is less concise than that of college algebra. Precollege, also referred to as remedial or developmental, mathematics includes courses in arithmetic, elementary algebra and intermediate algebra. Typically, remediation in reading, writing and mathematics is viewed together as one single entity, thus,

making it difficult to trace the origin of any single one. Even though Harvard has offered unprepared students assistance since its opening, the first remedial course is credited with being offered at Wellesley College in 1894 (Spann & McCrimmon, 1998). There is no mention of the subject matter of this first course.

During the 1970s, the field of developmental education experienced a surge in student enrollment and an expansion in the services offered to these students (Spann & McCrimmon, 1998). The CBMS 1980 survey found a 140% increase in remedial mathematics enrollment from 1970 to 1980 (as cited in Young, 1983). In fall 2000, 22% of all entering freshman enrolled in at least one remedial mathematics course (National Center for Education Statistics [NCES], 2000). According to the CBMS 2010 Survey, at four year colleges and universities, enrollment in precollege level mathematics courses increased 4% between 2005 and 2010. However, at two-year colleges, the enrollment increased 19% during the same time period.

The development of liberal arts mathematics courses began with the creation of courses involving the unification of mathematical topics (George, 2010). In 1923, regarding courses of this nature, J.W. Young argued:

To satisfy the demand as to the physical sciences our course must include the elements of trigonometry, linear and quadratic functions and equations, graphs, proportion and variation, familiarity with formulas and their use, and should certainly include if possible the fundamental ideas of the calculus and their applications. As to preparation for the social sciences (economics, etc.) we should want to include the elements of statistical methods, the elements of mathematics and finance and investment, as well as some of the topics previously listed. (p. 10)

An examination of 98 institutes of higher learning found 59 of the institutions offered at least one unified mathematics course during the previous ten years (Young, 1923).

Starting in the 1930s, the unified mathematics course designed for the general population of college students transitioned to the “survey” of mathematics course (George, 2010). The

following recommendation of the Special Committee on College Mathematics for Non-Science Students (1957), a subcommittee of the California Committee for the Study of Education, illustrates the lack of uniformity of “survey” courses that has existed since the formation of these courses:

Beyond such essential topics as the number system, operations with numbers, arithmetic of measurement, functions, graphs, equations and formulas, logical reasoning, the selection of topics should be influenced by the desires and abilities of the students, the interests of the teacher, and the amount of available time. Other topics which may be included are introduction to the calculus, probability and statistics, number theory and some elementary aspects of modern mathematics. In this work the objective will be more an attitude or point of view than a definite amount of knowledge or skill. Some history of mathematics, of important mathematical concepts and the role of mathematics in a world of scientific achievement should be interspersed throughout the entire course. (p. 641)

According to George (2010), “survey” courses were based in the “liberal arts” since they provided “a more ‘humanist’ experience than the traditional freshman courses in algebra, trigonometry, and analytic geometry” (p. 692).

During the 1950s, a new type of unified mathematics course that could be used as an additional option for satisfying the general mathematics education requirement was developed (Meyer, 2007). The new course titled *Finite Mathematics* centered on the mathematical needs of students majoring in a social science field. According to Meyer (2007), the first textbook written specifically for courses of this nature “combined symbolic logic, probability theory, game theory, matrix theory, linear programming, graph theory, and social science applications” (p. 106).

To investigate alignment of developmental and college level mathematics courses, Johnson (2007) analyzed the content of the elementary algebra, intermediate algebra, precalculus and math for liberal arts courses offered at one university. The results of the analysis indicated the content from both developmental mathematics courses together were

needed to form a proper foundation for precalculus (Johnson, 2007). However, the formation of a proper foundation for math for liberal arts required the content from elementary algebra with a few topics from intermediate algebra.

According to Cuban (2001a), starting in the late 1980s, a movement to improve the level of quality of undergraduate education began. However, in mathematics, the beginning of the movement appears to have begun during the late 1950s when the concept of math anxiety began to be acknowledged. For developmental and general education mathematics courses, math anxiety, students' ability to progress through the courses and the integration of technology were three lines of inquiry that appear to emerge during the late 1900s.

Math anxiety is commonly associated with poor performance in and avoidance of mathematics (Betz, 1978). The concept of "number anxiety" the predecessor to math anxiety, defined as "a syndrome of emotional reactions to arithmetic and mathematics" (Dreger & Aiken, 1957, p. 344), originated during the late 1950s. In their study involving university students enrolled in basic mathematics, Dreger and Aiken (1957) found that "number anxiety" possessed traits distinct from those of "general anxiety" and had an inverse relationship with grades earned in mathematics, $r = -.44$, p not reported, $n = 704$. Betz (1978) compared the levels of math anxiety among students enrolled in basic mathematics, precalculus and introductory psychology courses. The results of the study indicated that the basic mathematics students had a significantly higher level of math anxiety than both the precalculus and introductory psychology students, $F(2, 646) = 13.0$, $p < .001$ (Betz, 1978). There was no significant difference between the precalculus and introductory psychology students' levels of math anxiety.

In her study, Clute (1984) examined the impact two different instructional approaches had on students with low-, medium- and high-levels of math anxiety. The first approach was referred to as the direct instruction discovery method. It involved the instructor using questioning strategies to guide the students in their discovery of solutions to major mathematical problems. The second approach was referred to as the direct instruction expository method. It involved the instructor modeling a method of problem solving that the students could apply to follow up practice exercises. The results of the study indicated that students identified as having high-levels of math anxiety performed better when instructed by the expository method, whereas, the students with low- and mid-levels of math anxiety performed better when instructed by the discovery method, $F(2, 69) = 4.96, p < .01$ (Clute, 1984)..

In 2004, the U.S. Department of Education released a report that provided insight into students' ability to progress through undergraduate mathematics courses (Adelman, 2004). The findings are based on postsecondary transcripts collected as part of a national longitudinal study that followed students who were in 12th grade during 1992 until 2000. According to the findings, out of all of the different subjects taken by undergraduates, the three courses with the highest proportion of failures/penalty grades were developmental math, intermediate algebra and basic algebra, respectively (Adelman, 2004). General introductory college math, college algebra, precalculus and finite mathematics were also listed among the twenty courses with the highest proportions. Furthermore, out of all the different subjects taken by undergraduates, the four courses with the highest proportions of withdrawals and no credit repeats were basic algebra, intermediate algebra, college algebra and developmental math, respectively (Adelman, 2004). Precalculus, finite mathematics and

general introductory college math were also listed among the twenty courses with the highest proportions. Thus, developmental and general education math courses accounted for seven out of the twenty undergraduate courses having the highest proportions of failures and withdrawals.

In 2007, the Mathematical Association of America (MAA) released *Algebra: Gateway to a Technological Future*, a report designed to provide insight into the status of algebra in K-16 (Katz, 2007). Findings of the report were based on a review of research. The results indicated that less than 50% of students who enrolled in college algebra earned a C or better (Katz, 2007).

To further understand students' ability to progress through mathematics courses, studies exist that examined the effectiveness of development mathematics as a route into general education mathematics (Bahr, 2008; Gerlaugh, Thompson, Boylan & Davis, 2007). In a study of 29 two-year institutions of higher education over a period of two years, Gerlaugh, Thompson, Boylan and Davis (2007) found 80% of students who enrolled in a developmental mathematics course remained enrolled in the course until the end of the semester and, of those students, 68% were successful in completing the course. In addition, according to the results of the survey, 58% of the students who had satisfied the prerequisite of general education mathematics by successful completion of developmental mathematics were successful in completing their first college credit math course.

In a study of community colleges in California over a period of eight years, Bahr (2008) found 75% of students who initially enrolled in remedial mathematics did not successfully complete a college level mathematics course. Furthermore, the effectiveness of remedial mathematics as a gateway to academic attainment was examined. The levels of academic

attainment were categorized as (1) none, (2) certificate only, (3) degree with or without certificate, (4) transfer without credential, and (5) transfer with credential. The findings indicated that students who successfully completed both remedial mathematics and a college level mathematics course were able to reach levels of academic attainment comparable to those who successfully completed a college level mathematics course without taking remedial mathematics, $\beta = 0.14$, $p < .01$, $n = 85,894$. (Bahr, 2008). For both groups, approximately 20% did not complete a credential and did not transfer. In contrast, approximately 80% of the students who initially enrolled in remedial mathematics but were unable to successfully complete a college level mathematics course did not complete a credential and did not transfer (Bahr, 2008).

By the end of the twentieth century, advances in and access to technology offered educators new strategies for improving students' ability to progress through development and general education mathematics courses. According to NCTM, "Electronic technologies – calculators and computers – are essential tools for teaching, learning, and doing mathematics" (NCTM, 2000, p. 24). Improved access to technology came during the 1990s as a result of public officials and corporate leaders promoting the necessity of technology-based learning tools for school improvement (Cuban, 2001a). In response to this call for improvement, money was spent to increase the presence of technology in schools, colleges and universities.

Studies that investigated the effectiveness of technology-based learning tools integrated into developmental and general education mathematics courses varied on the emphasis placed on the technology. In three of the five studies identified, the effectiveness of the technology was the main focus of the investigation (Austin, 1996; Herman, 2007; Hauk & Segalla, 2005). In the other two studies identified, the effectiveness of redesigned courses

that included the integration of technology-based tools was the focus (Lucas & McCormick, 2007; McClory, 2003).

Two of the studies where the technology was the main focus examined the impact of graphing calculators on learning in college algebra. In a study of nine different college algebra sections taught by two different instructors, Austin (1996) found that students enrolled in sections taught by one of the instructors and who were permitted to use graphing calculators had significantly higher final examinations scores, $F(1, 171) = 4.51, p = .04$. However, the use of graphing calculators did increase student achievement for non-traditional students enrolled in the other instructor's sections, $F(1, 90) = 7.22, p = .01$. In her study, Herman (2007) investigated the impact graphing calculators had on students' methodology for solving algebraic problems. Solution strategies used by thirty-eight students were categorized as (1) symbolic manipulation, (2) graphical strategy and (3) tabular strategy. Herman (2007) found that students solved 68.2% of the questions on the posttest using a symbolic manipulation approach. Thus, the results of the study suggested that even though graphing calculators have features that foster the use of graphical and tabular strategies, students continued to select symbolic manipulation strategies. In addition, the graphing calculator was seen as a computational device with the added ability to check symbolic manipulation by way of a graph or table (Herman, 2007).

The third study where the technology was the main focus examined the impact of the web-based homework program, WeBWork, on learning in college algebra. In their study, Hauk and Segalla (2005) administered the same paper and pencil test at the beginning and end of the term to students in twelve sections of college algebra that assigned WeBWork homework and seven sections that assigned paper and pencil homework. The results of the

study indicated that there was no significant difference in students' performance between the two groups of students, statistical evidence not reported (Hauk & Segalla, 2005).

In the two studies that examined the effectiveness of redesigned courses that included the integration of technology-based tools, one study involved sections of a developmental mathematics course and the other involved sections of two different general education mathematics courses. In her study, McClory (2003) investigated the effect of mastery learning on the pass rate of students enrolled in a developmental mathematics course. Within this study, to demonstrate mastery and pass the course, students were required to score 70% or better on each test. The web-based tools consisted of a tutorial program and a testing program. During the semester immediately before the implementation of mastery learning, 30% of the total number of students enrolled in the different sections of the developmental mathematics course passed the course (McClory, 2003). Under mastery learning, the average pass rate of students rose to 73% per semester.

In their study, Lucas and McCormick (2007) investigated the impact liberal arts math and college algebra courses redesigned to better meet the needs of the students who were required to complete developmental mathematics had on students' success rates. During each semester, the course offerings included both the traditional courses and the redesigned courses, denoted with a K at the end of the course number. The technology-based tools consisted of online homework, virtual video instruction and a graphing calculator. At the end of the first year, results indicated 57% of the students in the traditional course who had completed developmental mathematics earned a C or better, compared to 70.5% in the redesigned liberal arts course (Lucas & McCormick, 2007). This difference was determined to be statistically significant, z not reported, $p < .001$, n not reported. Furthermore, 65.8% of

the students in the redesigned college algebra course earned a C or better, compared to 56.6% in the traditional course. This difference was determined to be not statistically significant, z not reported, $p = .95$, n not reported (Lucas & McCormick, 2007).

Even though a diverse body of literature exists centering on developmental and general education mathematics course work, the literature on the knowledge base, applicable to their future profession, teacher candidates develop as a result of taking courses in the arts and sciences is limited (Floden & Meniketti, 2009). Two studies were identified that examined the mathematical understanding of one mathematical concept teacher candidates possessed upon entering a teacher education program (Ball, 1990; Glidden, 2008). In her study, Ball (1990) examined the ability of elementary and secondary math teacher candidates in universities from across the country to select appropriate representations for division with fractions. The results indicated that 30% of the elementary teacher candidates and 40% of the secondary math were able to select an appropriate representation (Ball, 1990). To further understand the mathematical knowledge base of elementary, early childhood and special education teacher candidates, Glidden (2008) administered an examination consisting of four problems centering on the order of operations during the first class period of multiple sections of a two-semester mathematics content course designed for teacher candidates. The findings indicated that 54% of the teacher candidates answered two or fewer of the questions correctly (Glidden, 2008).

One study was identified that examined the mathematical competencies of elementary teacher candidates compared to the general college population (Rech, Harzell & Stephens, 1993). In the study, elementary teacher candidates completed a 48 question test which can be divided into 10 sub-categories of mathematics competencies. The test was administered at the

beginning of the semester to students enrolled in a mathematics course designed for elementary teacher candidates at one university over several semesters. The norms used in the comparison were established by administering the 48 question test to a group of students enrolled in one of various mathematics courses at four state colleges and 6 two-year institutions (Rech, Harzell & Stephens, 1993). The results suggested that elementary teacher candidates scored significantly lower on the test used to determine level of mathematical competency than the normative group, $t = -5.86, p < .001, n = 171$ (Rech, Harzell & Stephens, 1993). However, on 1 of the 10 sub-groups, elementary teacher candidates scored significantly higher than the normative group, $t = 5.22, p < .001, n = 171$.

One study was identified that examined the impact of general education mathematics on the knowledge base of elementary teacher candidates (Coughlin, 1968). In the study, the computational skills and understanding of fundamental mathematical concepts of prospective elementary teacher candidates enrolled in three different mathematics courses were examined. The three mathematics courses were (1) a regularly required liberal arts math course, (2) a modified version of the liberal arts math course, and (3) a mathematics course designed for elementary teacher candidates. The liberal arts courses were taught at one college in Michigan, whereas, the course designed for elementary teacher candidates was taught at a different university in the same state (Coughlin, 1968). In regards to computational skills, there was no significant difference between elementary teacher candidates in the modified liberal arts math course and in the mathematics for elementary teachers course, $F(1, 227) = .78, p$ not reported (Coughlin, 1968). In addition, there was no significant difference between elementary teacher candidates in the regularly required liberal arts math course and mathematics for elementary teachers course, $F(1, 266) = .04, p$ not

reported. Furthermore, there was no significant difference between elementary teacher candidates in the regularly required liberal arts math course and the modified liberal arts math course, $F(1, 105) = .69$, p not reported. In regards to understanding of fundamental mathematical concepts, there was no significant difference in the understanding of fundamental mathematical concepts between elementary teacher candidates enrolled in the modified liberal arts math course and the mathematics course designed for elementary teacher candidates, $F(1, 227) = 1.71$, p not reported. However, there was a significant difference between elementary teacher candidates enrolled in the regularly required liberal arts math course and the mathematics course designed for elementary teacher candidates, $F(1, 266) = 34.17$, $p < .01$. Furthermore, there was a significant difference between elementary teacher candidates enrolled in the modified liberal arts math course and the regularly required liberal arts math course and the mathematics course designed for elementary teacher candidates, $F(1, 105) = 11.39$, $p < .01$ (Coughlin, 1968).

Testing of Elementary Teacher Candidates in the United States

Prospective teachers have been subjected to testing to provide evidence of their competency to teach since the late nineteenth-century (Shulman, 1986). However, the movement of states to mandate this practice began in 1977 in the state of Louisiana (Sandefur, 1985). By 2000, forty-two states required that teacher candidates pass tests designed to assess competency in one or more of the areas of basic skills, general knowledge, content knowledge, or knowledge of teaching strategies (National Research Council, 2001b).

In 1998, Public Law 105-244 was enacted (National Research Council, 2001b). One of the goals of this legislation was to improve teacher preparation programs. As a result, the law mandated states to report:

The percentage of teaching candidates who passed each of the assessments used by the State for teacher certification and licensure, disaggregated and ranked, by teacher preparation programs in that State from which the teacher candidate received the candidate's most recent degree, which shall be made available widely and publicly. (as cited in National Research Council, 2001b, p. 199)

Programs that were deemed low-performing could face a reduction in federal funding.

In 1998, Educational Testing Service (ETS) released the document *The Use of Praxis Pass Rates to Evaluate Teacher Education Programs* to provide insight into the pass rate requirement of the law. At the time of the report, the U.S. House of Representatives had set the requirement that, to remain out of danger of losing federal funding, 70% of the graduates of a teacher preparation program had to pass the state's initial teacher licensing (ETS, 1998). However, the U.S. Senate revised it to 75%. In an examination of the *Elementary Education: Curriculum, Instruction, and Assessment Praxis* test pass rates from 1996 - 1997, ETS (1998) found that out of 30 teacher preparation programs considered for this study, 28 would have met a pass rate requirement of at least 70%. Furthermore, they found that 27 of the teacher preparation programs would have met a pass rate required of at least 75% (ETS, 1998).

The tests selected by states to be part of their teacher testing program reflect the emphasis policy makers place on various teacher competencies (National Research Council, 2001b). In a comparison of a teacher examination from the 1870s and ones from the early 1980s, Shulman (1986) concluded that the design of teacher examinations shifted from emphasizing content knowledge over pedagogy to pedagogy over content knowledge. In response to this finding, he cautioned, "But to blend properly the two aspects of a teacher's capacities

requires that we pay as much attention to the content aspects of teaching as we have recently devoted to the elements of teaching process” (Shulman, 1986, p. 8).

During the early 2000s, the state of Missouri used the *College BASE (CBASE)* examination for the testing of basic skills and the *Praxis II* series for testing subject matter competency (Missouri Department of Elementary and Secondary Education [DESE], n.d.). The *CBASE* is an examination developed by the Assessment Resource Center (ARC) housed at the University of Missouri-Columbia (DESE, n.d.). The examination is designed to assess knowledge and skills in language arts, mathematics, science and social studies. Scores reported include an overall composite score and an individual score for all four subject areas. Passing all four sections of the *CBASE* is required for admittance to an undergraduate teacher training program in Missouri.

To investigate gains in student learning as a result of attending college, Flowers, Osterlind, Pascarella and Pierson (2001) examined the *CBASE* scores of freshman, sophomores, juniors and seniors from fifty-six four year colleges. For the mathematics scores of males, the findings indicated that the senior versus freshmen effect size of .53 was the largest. For the mathematics scores of females, the sophomore versus freshmen effect size of .40, was the largest. (Flowers, Osterline, Pascarella & Pierson, 2001).

The *Praxis II* series of tests was developed by ETS, the Educational Testing Services (ETS, 2010). The tests in this series are designed to test content knowledge and instructional methods related to the various areas of certification (ETS, 2010). Passing the *Praxis II* test for the area designated as the teacher candidate’s primary area of certification is required for entry into the teaching profession in Missouri (DESE, n.d.).

After a review of available literature, the National Research Council (2001b) concluded, “Little research has been conducted on the extent to which scores on current teacher licensure tests related to other measures of beginning teacher competence” (p. 135). Two studies were identified that investigated various factors that have potential to influence teacher candidates’ performance on *Praxis II*. In their examination involving eight graduating classes from one college, Blue, O’Grady, Toro and Newell (2002) investigated the relationship between final college GPA and performance on the seven *Praxis* tests required for either elementary or early childhood certification. The findings indicated that the correlations between final college GPA at graduation and *Elementary Education Praxis* test scores were significant, $r = .55$, p not reported, n not reported (Blue, O’Grady, Toro & Newell, 2002). However, when the group was divided into high, middle and low subgroups, only one of the seven *Praxis* test scores was shown to be significantly correlated with the final college GPA of the low group.

In his study, Wall (2008) investigated the impact that formal training in an examination preparation model, referred to as T.E.S.T., had on *CBASE* composite and *Praxis II* scores of elementary teacher candidates enrolled in a teacher training program at one university from 1995 – 2007. In addition, he examined the correlation between *CBASE* and *Praxis II* scores. The findings indicated that there was a positive significant relationship between formal training in T.E.S.T. and both *CBASE* composite, $F = 9.25$, df not reported, $p < .001$. and *Praxis II*, $F = 4.97$, df not reported, $p < .05$, scores (Wall, 2008). In addition, the results suggested a positive significant correlation existed between *CBASE* composite and *Praxis II* scores, $r = .609$, $p < .001$, n not reported (Wall, 2008). However, when ACT scores were used as a covariate, formal training in T.E.S.T was shown to have a significant negative relationship to both scores.

One study was identified that did not use either the *CBASE* or *Praxis II* examinations but did investigate the relationship between a mathematical attribute of elementary teacher candidates and their score on a licensure examination. In their study, Capraro, Capraro, Parker, Kulm and Raulerson (2005) examined the impact core mathematics grades had on the *ExCET* licensure test of elementary teacher candidates in their senior year from 2001 to 2002 at one university. The investigation involved the content knowledge and pedagogical content knowledge portions of the *ExCET* examination. The findings indicated that a positive significant correlation existed between mathematics courses grades earned and the scores on the content knowledge portion of the *ExCET*, $r = .44$, $p < .01$, $n = 193$. This study provides evidence that further research into the impact developmental and general education mathematics course work individually have on scores on licensure examinations is needed.

Within this review of literature, the following four areas were examined: (1) P-12 student achievement in mathematics as it is related to their in-service teachers' content knowledge, (2) foundations of the mathematical training of elementary teachers in the United States, (3) presenting, developing and assessing mathematical subject content knowledge, and (4) testing of elementary teacher candidates in the United States. In the first section, evidence was provide to support the need for further inquiry into defining teachers' content knowledge defined by course work completed and test performance. The second section discussed the shift in the institutes responsible for the mathematical training of elementary teachers that occurred during the 1900s. The third section furnished information regarding the developmental and general education course work traditionally completed by teacher candidates. The fourth section discussed the high level of importance placed on standardized

licensure tests. All four areas combined suggest the present study will provide beneficial information to teacher education programs.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

This chapter provides a detailed description of the procedure that was followed in conducting the analysis of the relationship between the sequence of mathematics content courses completed by elementary teacher candidates and their performance on the *College BASE (CBASE)* and *Elementary Education Praxis II: Curriculum, Instruction & Assessment (Elementary Praxis II)*. This design used a longitudinal data set to gain more insight into the knowledge base teacher candidates develop as a result of the courses they complete to satisfy the mathematics requirement for certification at the elementary school level in the state of Missouri. This chapter will discuss the participants, procedures, instruments and research design used for this study.

Participants

Participants consisted of graduates of an undergraduate teacher training program from 2001 to 2011 at a private midsize university located in the state of Missouri. According to the student handbook of the School of Education at the university under study, criteria for entry into the undergraduate teacher training program include (1) the completion of at least forty-five semester hours of university work, (2) a cumulative GPA of at least 2.75 for all university work, (3) a grade of C or better in a general education mathematics course and (4) a passing score on all sections of the *CBASE*. To remain in the teacher training program, elementary teacher candidates must maintain an overall GPA of 2.75. To graduate from the program, elementary teacher candidates must earn a passing score on the *Elementary Praxis II*.

Procedures

Embedded in this study are two quasi-experimental designs with the grouping dependent on the undergraduate mathematics course needs of the individuals from 2001 to 2011. All information needed to perform the analysis was accessed through files housed in the School of Education of the university under study. Mathematics scores on *CBASE* and overall score on *Elementary Praxis II* for 104 elementary teacher candidates were entered into the database. Mathematics scores on *Elementary Praxis II* were only available for 65 of the teacher candidates. The representative in the School of Education who currently maintains the elementary teacher candidates' files had no knowledge as to the reason these scores were not included in all the files.

Elementary teacher candidates are required to complete only one general education mathematics course. At the university under study, those courses include: Finite Math, College Algebra, Precalculus and Calculus I. However, many of the teacher candidates enter the university without the necessary foundation in mathematics to enroll in a general education mathematics course. As a result, these teacher candidates are required to complete one or more developmental mathematics courses to develop the necessary foundation. At the university under study, those developmental courses are Introductory Algebra and Intermediate Algebra.

Since the general education and developmental mathematics courses are not required to be completed at the university under study, there was no means available to control for differences in the level of instruction or the teaching strategies used in these courses. However, an analysis of the table of content of textbooks used in these courses at various

institutes of higher education in the area was performed. The result of the analysis showed a consistency of core topics in these courses.

The use of a covariate and controlling for gender and race were considered. Potential covariates considered were ACT mathematics sub-score and GPA of mathematics courses completed in high school. Since not all of the teacher candidates in the study enrolled in the university immediately after graduating from high school, information regarding ACT and high school GPA was not included in all of the files. Considering gender and race, the Registration Office at the university under study indicated 97% of elementary teacher candidates from 2003 to 2011 to be female and 91% to be Caucasian. As a result, it was determined that use of a covariate or controlling for either gender or race was not feasible.

Nonequivalent groups were formed by using the number of developmental mathematics courses completed first, then by using the level of algebraic integration in general education mathematics course completed and, lastly, by using the two combined. The three groups formed using developmental mathematics course work were (1) teacher candidates who completed no developmental mathematics course, (2) teacher candidates who completed an intermediate algebra course only and (3) teacher candidates who completed the introductory algebra and intermediate algebra course sequence. The two groups formed using general education mathematics course work were (1) teacher candidates who completed a general education mathematics course that emphasized algebra, such as college algebra and (2) teacher candidates who completed a general education mathematics course that de-emphasized algebra, such as finite mathematics. The six groups formed using the two combined were (1) teacher candidates who completed no developmental mathematics course and a general education mathematics course that emphasized algebra, (2) teacher candidates

who completed an intermediate algebra course only and a general education mathematics course that emphasized algebra, (3) teacher candidates who completed the introductory algebra and intermediate algebra course sequence and a general education mathematics course that emphasized algebra, (4) teacher candidates who completed no developmental mathematics course and a general education mathematics course that de-emphasized algebra, (5) teacher candidates who completed an intermediate algebra course only and a general education mathematics course that de-emphasized algebra and (6) teacher candidates who completed the introductory algebra and intermediate algebra course sequence and a general education mathematics course that de-emphasized algebra.

The undergraduate mathematics course needs of the teacher candidates produced groups of varying sizes. Of the 104 teacher candidates, 52 (50%) completed no developmental mathematics course, 21 (20.19%) completed intermediate algebra only and 31 (29.81%) completed the introductory algebra and intermediate algebra course sequence. Furthermore, 78 (75%) completed a general education mathematics course that emphasized algebra and 26 (25%) completed one that de-emphasized algebra (see Table 1). Of the 65 teacher candidates whose file contained a mathematics score on *Elementary Praxis II*, 30 (46.15%) completed no developmental mathematics course, 12 (18.46%) completed an intermediate algebra course only and 23 (35.38%) completed the introductory algebra and intermediate algebra course sequence.

Furthermore, 49 (75.38%) completed a general education mathematics course that emphasized algebra and 16 (24.62%) completed one that de-emphasized algebra (see Table 2).

Table 1

Developmental Mathematics Course Work by General Education Course Work (Entire Sample)

Developmental Mathematics	General Education Mathematics		Total
	Emphasized Algebra	De-emphasized Algebra	
None	36 (34.62)	16 (15.38)	52 (50)
Intermediate Algebra Only	18 (17.31)	3 (2.88)	21 (20.19)
Introductory/Intermediate Algebra Sequence	24 (23.08)	7 (6.73)	31 (29.81)
Total	78 (75)	26 (25)	104 (100)

Note. Values enclosed in parentheses represent percentages.

Table 2

Developmental Mathematics Course Work by General Education Course Work (Praxis Math Sample)

Developmental Mathematics	General Education Mathematics		
	Emphasized Algebra	De-emphasized Algebra	Total
None	21 (32.31)	9 (13.85)	30 (46.15)
Intermediate Algebra Only	10 (15.38)	2 (3.08)	12 (18.46)
Introductory/Intermediate Algebra Sequence	18 (27.69)	5 (7.69)	23 (35.38)
Total	49 (75.38)	16 (24.62)	65 (100)

Note. Values enclosed in parentheses represent percentages.

The measures used for this analysis were teacher candidates' scores from *College BASE* (*CBASE*) and *Elementary Education Praxis II: Curriculum, Instruction & Assessment* (*Elementary Praxis II*). The mathematics scores on *CBASE* and the overall score on *Elementary Praxis II* were used in the first analysis. The mathematics scores on the *Elementary Praxis II* were used for the second analysis. All elementary teacher candidates' mathematics scores on *CBASE* and overall score on *Elementary Praxis II* are on file in the School of Education. However, for some reason unknown to the researcher, the summary report sent by the Educational Testing Services (ETS) to the university under study contained the mathematics score on *Elementary Praxis II* for only 65 of the 104 elementary teacher candidates. Therefore, a separate analysis was performed on the data set involving only the 65 teacher candidates whose files contained this score.

Instruments

Over the last decade, elementary teacher candidates have been required to earn a score of 235 on all sections of the *CBASE* to be admitted to any undergraduate teaching training program in Missouri (Missouri Department of Elementary and Secondary Education [DESE], n.d.). The *CBASE* was developed by the Assessment Resource Center (ARC) housed at the University of Missouri-Columbia. According to ARC (n.d.), "*College BASE*, a criterion-referenced academic achievement examination, evaluates knowledge and skills in English, mathematics, science and social studies, usually after a student completes a college-level core curriculum" (p. 1). Furthermore, ARC indicated experts in the various subject areas of the college-level core curriculum from across the country were involved in the development of the test. Past studies that "include quantitative indices of item-skill congruence and canonical

correlations of *College BASE* test scores with the criteria of GPA, ACT scores, and SAT Quantitative and Verbal scores” (ARC, n.d., p. 8) provide evidence of validity.

The *CBASE* consists of 180 multiple choice questions with 56 of them pertaining to mathematics. Mathematics scores on the *CBASE* range from 40 to 560 points. The ARC reported a reliability index of .91 for the mathematics strand of the *CBASE* (ARC, n.d.). Furthermore, the reliability index of the *CBASE* subject test scores has remained unchanged since its development (ARC, n.d.).

Over the last decade, elementary teacher candidates have been required to earn an overall score of 164 on the *Elementary Education Praxis II: Curriculum, Instruction & Assessment (Elementary Praxis II)* to graduate from any undergraduate teaching training program in Missouri (DESE, n.d). The *Elementary Praxis II* was developed by the Educational Testing Services (ETS). Test questions cover the subject areas of reading, language arts, mathematics, science, social studies, arts and physical education. In addition, the teacher candidates’ knowledge of curriculum, instruction and assessment is assessed as it relates to the different subject areas and in general.

To ensure the validity of the test, test developers consulted multiple sources of professional knowledge throughout the development process (ETS, 2010). Sources included: professional literature, content standards, individuals appointed by ETS to a National Advisory Committee, practitioners who possessed an occupational perspective and other experts in the field. Experts, not associated with ETS, were involved with determining the skills and knowledge to be tested, writing actual test items and evaluating a final draft of the test.

The *Elementary Praxis II* consists of 110 multiple choice questions with approximately 22 of them pertaining to mathematics. The overall score on the *Elementary Praxis II* ranges from 100 to 200. The mathematics score on the *Elementary Praxis II* ranges from 0 to 24. In 2010, ETS reported a reliability index of .85 for the overall score of the *Elementary Praxis II*. The reliability index is not provided for the mathematics strand of the test. ETS cautions that use of the subtests scores may not be reliable.

Data Analysis

This study was designed to investigate the impact the sequence of mathematics content courses completed had on the mathematics strand performance on *CBASE*, on the overall performance on *Elementary Praxis II* and on the mathematics strand performance on *Elementary Praxis II*. The data analyses were selected to provide insight into the following nine research questions: (1) Is there an interaction effect between developmental and general education mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates? (2) Is there a main effect between developmental mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates? (3) Is there a main effect between general education mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates? (4) Is there an interaction effect between developmental and general education mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates? (5) Is there a main effect between developmental mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates? (6) Is there a main effect between general education mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates? (7) Is there an interaction effect between developmental and

general education mathematics course work and the mathematics subtest scores on *Elementary Praxis II* of elementary teacher candidates? (8) Is there a main effect of developmental mathematics course work and the mathematics subtest scores on *Elementary Praxis II* of elementary teacher candidates? (9) Is there a main effect of general education mathematics course work and the mathematics subtest scores on *Elementary Praxis II* of elementary teacher candidates?

Descriptive statistics in this study were used to provide insight into the distribution of mathematics scores on *CBASE*, overall scores on *Elementary Praxis II* and mathematics scores on *Elementary Praxis II* within each group needed for the analysis. These statistics described the sample size, minimum, maximum, mean and standard deviation. In addition, descriptive statistics were used to check some of the assumptions of the tests being performed. These statistics were used for evaluating univariate outliers, multivariate outliers and normality. Level of significances recommended by Tabachnick and Fidell (2013) were used in the checking of assumptions.

Inferential statistics, multivariate analysis of variance (MANOVA) and analysis of variance (ANOVA), were used to explore the previously stated research questions. The level of significance of .05 was determined to be acceptable for all statistical comparisons.

Research Design

Two types of analysis, MANOVA and ANOVA, were performed using SPSS. The researcher tested for univariate outliers and checked for missing data prior to performing any analysis. In addition, assumptions of normality, independence of observations, correlation of dependent variables, linearity, homogeneity of variance and homogeneity of variance-covariance matrices were tested.

A two-way MANOVA was used to investigate the interaction of two factors on two dependent variables. Furthermore, two separate follow-up analyses using ANOVA on each of the dependent variables were performed. The two factors were developmental mathematics course work and general education mathematics course work. The factor of developmental mathematics course work is a nominal variable with the three levels: (1) teacher candidates who completed no developmental mathematics course, (2) teacher candidates who completed an intermediate algebra course only and (3) teacher candidates who completed the introductory algebra and intermediate algebra course sequence. These three levels are referred to as (1) None, (2) Intermediate Algebra Only and (3) Introductory/Intermediate Algebra Sequence in the analysis. The factor of general education mathematics course work is a nominal variable with the two levels of (1) teacher candidates who completed a general education mathematics course that emphasized algebra, such as college algebra precalculus and calculus I, and (2) teacher candidates who completed a general education mathematics course that de-emphasized algebra, such as finite mathematics. These two levels are referred to as (1) Course Emphasized Algebra and (2) Course De-emphasized Algebra in the analysis. The treatment was the combination of the two factors.

The two dependent variables were mathematics scores on *CBASE* (*CBASE Math*) and overall score on *Elementary Praxis II* (*Praxis Overall*). Teacher candidates at the university under study are permitted to attempt the *CBASE* up to three times and the *Elementary Praxis II* an unlimited number of times. Gall, Gall and Borg (2007) cautioned that, due to the influence of becoming “test-wise”, scores might become inflated with each retake of different versions of the same test. As a result, the mathematics scores on *CBASE* and overall

score on *Elementary Praxis II* from the teacher candidates' first attempt were used for the analysis.

A two-way ANOVA was performed to investigate the interaction of the two factors on the mathematics score on *Elementary Praxis II (Praxis Math)*. The mathematics scores on *Elementary Praxis II* from the teacher candidates' first attempt were used in the analysis. Only 65 of the 104 teacher candidates' files contained the score needed for this analysis, which did not allow for inclusion of this dependent variable into the analysis involving MANOVA.

CHAPTER 4

RESULTS

Introduction

The purpose of this study was to examine the relationship between the sequence of mathematics content courses completed by elementary teacher candidates and their performance on the *College BASE (CBASE)* and *Elementary Education Praxis II: Curriculum, Instruction & Assessment (Elementary Praxis II)*. This chapter provides the results of the statistical analyses for investigating the following nine research questions: (1) Is there an interaction effect between developmental and general education mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates? (2) Is there a main effect between developmental mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates? (3) Is there a main effect between general education mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates? (4) Is there an interaction effect between developmental and general education mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates? (5) Is there a main effect between developmental mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates? (6) Is there a main effect between general education mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates? (7) Is there an interaction effect between developmental and general education mathematics course work and the mathematics subtest scores on *Elementary Praxis II* of elementary teacher candidates? (8) Is there a main effect of developmental mathematics course work and the mathematics subtest scores on *Elementary Praxis II* of

elementary teacher candidates? (9) Is there a main effect of general education mathematics course work and the mathematics subtest scores on *Elementary Praxis II* of elementary teacher candidates?

Data Analysis

To evaluate the impact of the sequence of mathematic content courses completed by elementary teacher candidates, the dependent variables of mathematics score on *CBASE* (*CBASE* Math), overall score on *Elementary Praxis II* (*Praxis* Overall) and mathematics score on *Elementary Praxis II* (*Praxis* Math) were used. All of the 104 teacher candidates in the study had a mathematics score from the *CBASE* and an overall score from the *Elementary Praxis II* on file. These scores can range from 40 to 560 and from 100 to 200, respectively. Of the 104 teacher candidates, only 65 of them had a mathematics score from the *Elementary Praxis II* on file. These scores can range from 0 to 24.

Due to the reduced number of teacher candidates who had a mathematics score from the *Elementary Praxis II* on file, two quasi-experimental designs were needed in this study. Both designs used the two factors of developmental course work and general education mathematics course work completed by the teacher candidates. Developmental course work had three values: (1) None, (2) Intermediate Algebra Only and (3) Introductory Algebra and Intermediate Algebra Sequence. General education mathematics course work had two levels: (1) Course Emphasized Algebra and (2) Course De-emphasized Algebra. The treatment was the combination of the two factors.

Descriptive statistics in this study were used to provide insight into the distribution of mathematics scores on *CBASE*, overall scores on *Elementary Praxis II* and mathematics scores on *Elementary Praxis II* of each group needed for the analyses. As can be seen in

Table 3, when considering the mathematics scores on the *CBASE* of teacher candidates in this study, the group who completed no developmental mathematics course and a general education mathematics course that emphasized algebra had the highest mean of 311.33 with a standard deviation of 40.09. The group of teacher candidates who completed the introductory algebra and intermediate algebra sequence and a general mathematics course that de-emphasized algebra had the lowest mean of 277.57 with a standard deviation of 35.73.

As can be seen in Table 4, when considering the overall scores on *Elementary Praxis II* of teacher candidates in this study, the group who completed intermediate algebra only and a general education mathematics course that de-emphasized algebra had the highest mean of 182.67 with a standard deviation of 5.03. The group of teacher candidates who completed intermediate algebra only and a general education mathematics course that emphasized algebra had the lowest mean of 174.28 with a standard deviation of 12.38.

As can be seen in Table 5, when considering the mathematics scores on *Elementary Praxis II* of teacher candidates in this study, the group who completed intermediate algebra only and a general education mathematics course that emphasized algebra had the highest mean of 16.70 with a standard deviation of 2.63. The group of teacher candidates who completed the introductory algebra and intermediate algebra sequence and a general education mathematics course that de-emphasized algebra had the lowest mean of 15.40 with a standard deviation of 2.30.

Table 3

Analysis of CBASE Math Scores

----- General Education Mathematics that Emphasized Algebra -----

Developmental Mathematics	N	Minimum	Maximum	Mean	Std Dev
None	36	245.00	412.00	311.33	40.09
Intermediate Algebra Only	18	196.00	373.00	288.50	53.02
Introductory/Intermediate Algebra Sequence	24	222.00	376.00	298.46	39.48

----- General Education Mathematics that De-emphasized Algebra -----

Developmental Mathematics	N	Minimum	Maximum	Mean	Std Dev
None	16	205.00	364.00	280.31	41.80
Intermediate Algebra Only	3	223.00	342.00	283.33	59.52
Introductory/Intermediate Algebra Sequence	7	226.00	330.00	277.57	35.73

Table 4

Analysis of Praxis Overall Scores

----- General Education Mathematics that Emphasized Algebra -----

Developmental Mathematics	N	Minimum	Maximum	Mean	Std Dev
None	36	161.00	191.00	176.42	7.90
Intermediate Algebra Only	18	156.00	194.00	174.28	12.38
Introductory/Intermediate Algebra Sequence	24	148.00	195.00	176.83	12.98

----- General Education Mathematics that De-emphasized Algebra -----

Developmental Mathematics	N	Minimum	Maximum	Mean	Std Dev
None	16	152.00	191.00	174.38	12.16
Intermediate Algebra Only	3	178.00	188.00	182.67	5.03
Introductory/Intermediate Algebra Sequence	7	160.00	190.00	174.43	12.27

Table 5

Analysis of Praxis Math Scores

----- General Education Mathematics that Emphasized Algebra -----					
Developmental Mathematics	N	Minimum	Maximum	Mean	Std Dev
None	21	11.00	23.00	16.48	2.89
Intermediate Algebra Only	10	13.00	21.00	16.70	2.63
Introductory/Intermediate Algebra Sequence	18	11.00	21.00	16.39	2.89
----- General Education Mathematics that De-emphasized Algebra -----					
Developmental Mathematics	N	Minimum	Maximum	Mean	Std Dev
None	9	13.00	20.00	15.89	2.26
Intermediate Algebra Only	2	13.00	20.00	16.50	4.95
Introductory/Intermediate Algebra Sequence	5	13.00	19.00	15.40	2.30

Two types of analysis, MANOVA and ANOVA, were performed using SPSS. A two-way MANOVA was used to investigate the interaction of the two factors on the two dependent variables of mathematics scores on *CBASE* (*CBASE Math*) and overall score on *Elementary Praxis II* (*Praxis Overall*). Furthermore, two separate follow-up analyses using two-way ANOVA on each of the dependent variables were performed. In addition, a two-way ANOVA was performed to investigate the interaction of the two factors on the mathematics score on *Elementary Praxis II* (*Praxis Math*).

The two factors for all the analyses were the number of developmental courses and the level of algebraic integration in general education mathematics course completed by the elementary teacher candidates in the study. As indicated before, development course work had three values: (1) None, (2) Intermediate Algebra Only and (3) Introductory/Intermediate Algebra Sequence. General education mathematics course work had two levels: (1) Course Emphasized Algebra and (2) Course De-emphasized Algebra.

A 3×2 two-way MANOVA was used to investigate the interaction of the two factors on the *CBASE Math* and *Praxis Overall*. The order of the two factors was developmental course work (None, Intermediate Algebra Only, Introductory/Intermediate Algebra Sequence), then general education mathematics course work (Course Emphasized Algebra, Course De-emphasized Algebra). The treatment was the combination of the two factors. All 104 teacher candidates were included in this analysis.

Prior to performing any of the analyses, *CBASE Math* and *Praxis Overall* scores were examined to check for outliers and normality. Level of significances recommended by Tabachnick and Fidell (2013) were used. Corresponding z-scores for both *CBASE Math* and *Praxis Overall* scores were calculated for data grouped by developmental mathematics

course work, general mathematics course work and the six groups formed by the combination of the two. Using a level of significance of .001 for a two-tailed test, the z-scores indicated no univariate outliers existed. In addition, Mahalanobis Distances were calculated to examine the presence of multivariate outliers. Using a level of significance of .001, the Mahalanobis Distances indicated no multivariate outliers existed.

Normality was examined for all grouped data needed for the analyses. Using a level of significance of .05, Shapiro-Wilk's values for all the grouped data were shown to be non-significant. In addition, skewness and kurtosis z-scores were calculated. A level of significance of .01 for a two tailed test was used for both skewness and kurtosis. When considering skewness, no issues existed. When considering kurtosis, one issue existed. The values of kurtosis for the group consisting of the 3 teacher candidates who completed intermediate algebra only and a general education mathematics course that de-emphasized algebra were not able to be calculated by SPSS. However, using an alternative method suggested by Joanes and Gill (1998), the values of the sample excess kurtosis for both *CBASE* Math and *Praxis* Overall scores were calculated to both be between -3 and -2. Since the resulting values of kurtosis are less than zero, the distributions are considered to be flat and not similar to a normal distribution.

Assumptions of independence of observations, correlation of dependent variables, linearity, homogeneity of variance and homogeneity of variance-covariance matrices were checked. The assumption of observations being independent was assumed to hold since the participants completed their course work at various institutions of higher education. According to Tabachnick and Fidell (2013), MANOVA performs fairly well when the correlation between dependent variables is approximately .6 or -.6. The correlation between

the dependent variables of *CBASE* Math and *Praxis* Overall was shown to be .41 which was determined to be acceptable.

To check for linearity, individual scatter plots for all grouped data needed for the analyses comparing *CBASE* Math and *Praxis* Overall scores were examined. All scatter plots had reasonably balanced distributions, thus, indicating no issues with linearity. Levene's Test was used to test for homogeneity of variance. The variances for *CBASE* Math scores were not significantly different ($F = 0.93, p = .46$). However, the variances for *Praxis* Overall scores were significantly different ($F = 3.24, p < .05$). Thus, the assumption of homogeneity of variance was not met. Various transformations were performed to improve the homogeneity of variance. However, the original *Praxis* Overall scores were used in the analysis since the desired improvement to the homogeneity of variance did not occur. According to the Box Test, the assumption of homogeneity of variance-covariance matrices was met ($F = 0.89, p = .57$).

The results of the 3×2 two-way MANOVA involving the factors of developmental mathematics courses (DevMath) and general education mathematics course (GenEdMath), and the dependent variables of mathematics score on *CBASE* and overall score on *Elementary Praxis II* combined are provided in Table 6. Using Wilks' criterion, the results revealed no interaction or main effects involving the developmental course work or general education course work on *CBASE* Math and *Praxis* Overall combined exist. However, due to the low level of power, these results are recommended to be interpreted with caution.

Two separate follow-up 3×2 ANOVAs on each of the dependent variables were performed. As seen in Table 7, the results revealed no interaction or main effects involving developmental course work or general education course work on *CBASE* Math exist. In

addition, as seen in Table 8, the results revealed no interaction or main effects involving developmental course work or general education course work on *Praxis* Overall exist. However, due to the occurrence of the low levels of power when an alpha level of .05 is used, these results are recommended to be interpreted with caution.

Table 6

CBASE Math and Praxis Overall Combined: 3(DevMath) x 2(GenEdMath) Multivariate Analysis of Variance

	F	Sig.	Power
DevMath	0.53	.71	.18
GenEdMath	2.05	.14	.41
DevMath*GenEdMath	0.59	.67	.19

Table 7

CBASE Math: 3(DevMath) x 2(GenEdMath) Analysis of Variance

	F	Sig.	Power
DevMath	0.37	.69	.11
GenEdMath	2.66	.11	.07
DevMath*GenEdMath	0.41	.67	.23

Table 8

Praxis Overall: 3(DevMath) x 2(GenEdMath) Analysis of Variance

	F	Sig.	Power
DevMath	0.34	.72	.11
GenEdMath	0.19	.66	.37
DevMath*GenEdMath	1.03	.36	.11

A 3×2 ANOVA was used to investigate the interaction of two factors on the *Praxis* Math. The order of the two factors was developmental course work (None, Intermediate Algebra Only, Introductory/Intermediate Algebra Sequence), then general education mathematics course work (Course Emphasized Algebra, Course De-emphasized Algebra). The 65 teacher candidates whose files contain a mathematics score on *Elementary Praxis II* were included in this analysis.

Prior to performing the analysis, *Praxis* Math scores were examined to check for outliers, normality and correlation with *CBASE* Math scores. Level of significances recommended by Tabachnick and Fidell (2013) were used. Corresponding z-scores for *Praxis* Math scores were calculated for data grouped by developmental mathematics course work, general mathematics course work and the six groups formed by the combination of the two. Using a level of significance of .001 for a two tailed test, the z-scores indicated no univariate outliers existed. Normality was examined for all grouped data needed for the analyses. Using a level of significance of .05, with the exception of one group, Shapiro-Wilk's values for all grouped data were shown to be non-significant. The group of teacher candidates who completed a general education mathematics course that de-emphasized algebra was the only group whose *Praxis* Math scores violated the assumption of normality ($p < .05$).

Skewness and kurtosis z-scores were also calculated. A level of significance of .01 for a two tailed test was used for both skewness and kurtosis. When considering skewness, no issues existed. When considering kurtosis, one issue existed. The value of kurtosis for the group consisting of the 2 teacher candidates who completed intermediate algebra only and a general education mathematics course that de-emphasized algebra was not able to be calculated using SPSS. However, using an alternative method suggested by Joanes and Gill

(1998), the value of the sample excess kurtosis for *Praxis* Math scores was calculated to be between -3 and -2. Since the resulting value of kurtosis is less than zero, the distribution is considered to be flat and not similar to a normal distribution. The correlation between the dependent variables of *CBASE* Math and *Praxis* Math was shown to be .46. Hence, even though a relationship does exist between *CBASE* Math and *Praxis* Math, the magnitude of the correlation indicates additional insight may be gained when considering the impact developmental and general education mathematics course work has on the *Praxis* Math scores of elementary teacher candidates.

Assumptions of independence of observations and homogeneity of variance were checked. The assumption of observations being independent was assumed to hold since the participants completed their course work at various institutions of higher education. Levene's Test was used to test for homogeneity of variance. The variances for *Praxis* Math scores were not significantly different ($F = 0.60, p = .70$). Thus, the assumption of homogeneity of variance was met.

The results of the 3×2 two-way ANOVA involving the factors of developmental mathematics courses (DevMath) and general education mathematics course (GenEdMath), and the dependent variable of mathematics score on *Elementary Praxis II* (*Praxis* Math) are provided in Table 9. The results revealed no interaction or main effects involving developmental course work or general education course work on *Praxis* Math exist. However, due to the occurrence of the low levels of power when an alpha level of .05 is used, these results are recommended to be interpreted with caution.

Summary

The occurrence of having no interaction and main effects leads to questions regarding the knowledge gained by the study performed. In this study, the focus was on the impact of both the number of developmental mathematics courses and the level of algebra integration of general education mathematics courses completed had on test scores of elementary teacher candidates. The tests used in the study were ones used to gain entrance into teacher education programs and the teaching profession in Missouri. As a result, the absence of interaction and main effects in this study show that the teacher candidates who entered college with deficiencies in mathematics or completed a general education mathematics course that de-emphasized algebra were not at a disadvantage for passing the tests need for obtaining teaching credentials in Missouri based on the available data information. To increase the generalizability of the results of this study, one of my future goals is to perform another study, similar in nature, using a larger set of data.

Table 9

Praxis Math: 3(DevMath) x 2(GenEdMath) Analysis of Variance

	F	Sig.	Power
DevMath	0.15	.86	.08
GenEdMath	0.40	.53	.10
DevMath*GenEdMath	0.05	.95	.06

CHAPTER 5

DISCUSSION

Summary of the Study and Its Findings

The purpose of this study was to examine the relationship between the sequence of mathematics content courses completed by elementary teacher candidates and their performance on the *College BASE (CBASE)* and *Elementary Education Praxis II: Curriculum, Instruction & Assessment (Elementary Praxis II)*. Mathematics scores on *CBASE* and overall scores on *Elementary Praxis II* of teacher candidates in an undergraduate teacher training program from 2001 to 2011 at a private midsize university located in the state of Missouri were analyzed ($n = 104$). Mathematics scores on *Elementary Praxis II* of those teacher candidates whose file contained the score were also analyzed ($n = 65$).

The following nine research hypotheses were tested:

- 1) There will be an interaction effect between developmental and general education mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates.
- 2) There will be a main effect between developmental mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates.
- 3) There will be a main effect between general education mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates.
- 4) There will be an interaction effect between developmental and general education mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates.

- 5) There will be a main effect between developmental mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates.
- 6) There will be a main effect between general education mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates.
- 7) There will be an interaction effect between developmental and general education mathematics course work and the mathematics subtest scores on *Elementary Praxis II* of elementary teacher candidates.
- 8) There will be a main effect of developmental mathematics course work and the mathematics subtest scores on *Elementary Praxis II* of elementary teacher candidates.
- 9) There will be a main effect of general education mathematics course work and the mathematics subtest scores on *Elementary Praxis II* of elementary teacher candidates.

Mathematics scores on *CBASE* and overall scores on *Elementary Praxis II* were analyzed using a 3×2 two-way MANOVA. Two follow-up 3×2 ANOVAs were performed on mathematics scores on *CBASE* and overall scores on *Elementary Praxis II* separately.

Mathematics scores on *Elementary Praxis II* scores were analyzed using a 3×2 two-way ANOVA. In all of the tests, the order of the two factors was developmental course work (None, Intermediate Algebra Only, Introductory/Intermediate Algebra Sequence), then general education mathematics course work (Course Emphasized Algebra, Course De-emphasized Algebra).

Results of the analyses for the test scores are summarized by hypothesis as follows:

Hypothesis 1: Results of the multivariate analysis of variance and analysis of variance indicated there was not a significant interaction effect of developmental mathematics course

work and general mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates.

Hypothesis 2: Results of the multivariate analysis of variance and analysis of variance indicated there was not a significant main effect of developmental course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates.

Hypothesis 3: Results of the multivariate analysis of variance and analysis of variance indicated there was not a significant main effect of general education mathematics course work and the mathematics subtest scores on *CBASE* of elementary teacher candidates.

Hypothesis 4: Results of the multivariate analysis of variance and analysis of variance indicated there was not a significant interaction effect of developmental mathematics course work and general mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates.

Hypothesis 5: Results of the multivariate analysis of variance and analysis of variance indicated there was not a significant main effect of developmental course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates.

Hypothesis 6: Results of the multivariate analysis of variance and analysis of variance indicated there was not a significant main effect of general education mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates.

Hypothesis 7: Results of the analysis of variance indicated there was not a significant interaction effect of developmental mathematics course work and general mathematics course work and the overall scores on *Elementary Praxis II* of elementary teacher candidates.

Hypothesis 8: Results of the analysis of variance indicated there was not a significant main effect of developmental course work and the mathematics subtest scores on *Elementary Praxis II* of elementary teacher candidates.

Hypothesis 9: Results of the analysis of variance indicated there was not a significant main effect of general education mathematics course work and the mathematics subtest scores on *Elementary Praxis II* of elementary teacher candidates.

Limitations of the Study

Initially, there were five limitations of this study. First, the uniqueness of the university may hinder the ability to generalize this study. Traditionally, elementary teacher candidates at this university tend to be Caucasian females. According to the Registration Office at the university under study, 97% of students who were awarded a degree in elementary education from 2003 to 2011 were females. Furthermore, 91% were Caucasian. Thus, males and minorities were underrepresented in the present study.

Secondly, it is recommended that elementary teacher candidates attempt the *CBASE* upon completion of their content mathematics course sequence and the *Elementary Praxis II* upon completion of their mathematics methods courses. However, the timeline of the course work and tests cannot be guaranteed. Thirdly, use of the mathematics score on *Elementary Praxis II* was the one predicted to provide the most information in regard to the impact of content course sequencing. However, until recently, those scores were not provided to the university from the provider of the test, Educational Testing Service (ETS), for all the teacher candidates who had completed the test. Also, ETS cautions that use of the subtests' scores may not be reliable.

Fourth, by nature, the design of the study is quasi-experimental. The grouping is dependent on the undergraduate mathematics course needs of the individuals. Fifth, the researcher had no control over the level of instruction of the actual mathematics course work completed.

Two other limitations emerged during the analysis of the data. First, some of the assumptions were not met. For all of the test scores used in the two analyses, the value of kurtosis of the group consisting of teacher candidates who completed intermediate algebra only and a general education mathematics course that de-emphasized algebra indicated that none of the distributions similar to a normal distribution. The assumption of homogeneity of variance was not met for overall scores on *Elementary Praxis II*. The mathematics scores on *Elementary Praxis II* for the group of teacher candidates who completed a general education mathematics course that de-emphasized algebra violated the assumption of normality.

The second limitation that emerged during the analysis of the data was the resulting low levels of power. Since power measures the ability to detect a significant difference when there actually is one, a level of power level between .70 and .80 is wanted (Stevens, 1999). In the present study, the power for the results ranged from .06 to .41, well below the desired range. To raise the level of power, Stevens (1999) recommends increasing the number of subjects per group. Furthermore, he recommends reducing group variability by using more homogeneous subjects within each group or by adding a controlling variable. Unfortunately, for the present study, it was not possible for the researcher to acquire a larger data set or to add a controlling variable to reduce the random error. As a result of all the limitations, caution should be used when interpreting and generalizing the results. Thus, even though the results of the present study indicate there was no impact of developmental course work on

the mathematics scores on *CBASE*, the overall scores on *Elementary Praxis II* and the mathematics scores on *Elementary Praxis II*, replication of the study on a larger group of teacher candidates is recommended.

Discussion

In their 1995 book titled *The Manufactured Crisis: Myths, Fraud, and the Attack on America's Public Schools*, Berliner and Biddle observed, in reference to the report *A Nation at Risk*:

Never before had an American government been so critical of the public schools, and never had so many false claims been made about education in the name of "evidence." We shall refer to this campaign of criticism as the Manufactured Crisis. (p. 4)

The authors claimed one such criticism was "*A Nation at Risk* charged that American students never excelled in international comparisons of student achievement and that this failure reflected systematic weaknesses in our school programs and lack of talent and motivation among American educators" (Berliner & Biddle, 1995, p. 3). Even though the Constitution of the United States gives the primary responsibility of education to the states, during the 1980s, there was a shift towards more federal government involvement in this arena.

According to Shaker (2001), "origins of the current mania for teacher testing in America can be traced to the alarmist claims of *A Nation at Risk*" (p. 80). Since the publication of *A Nation at Risk*, two public laws were enacted that promoted the use of teacher testing to ensure teacher quality. Public Law 105-244, enacted in 1998, mandated that states report "The percentage of teaching candidates who passed each of the assessments used by the State for teacher certification and licensure" (as cited in National Research Council, 2001b, p. 199). Furthermore, the percentage of teacher candidates who passed each of the assessments

was to be used to differentiate between the level of quality of teacher training programs within the United States.

Public Law 107-110, referred to as the No Child Left Behind Act (NCLB) of 2001, was enacted in 2002. The Highly Qualified Teacher (HQT) mandate of the NCLB required all states provide evidence that, before entering into the field, an elementary teacher candidate in the state “has demonstrated by passing a rigorous State test, subject knowledge and teaching skills in reading, writing, mathematics, and other areas of the basic elementary school curriculum” (NCLB, 2002, p. 1960). According to Berlinder and Biddle (1995), in the 1980s, leaders in government and industry promoted the myth that “Those who enter teaching have little ability and receive a poor academic education” (p. 102).

The enactment of PL 105-244 and PL 107-110 suggest that policymakers at the federal level deemed performance on standardized tests as a reliable indicator of not only teacher quality but of the quality of U.S. teacher training programs. As a result, leaders of higher education need research-based evidence of the effectiveness of various elements of their programs in order to make informed decisions. The present study examines the impact mathematics course work completed as part of an undergraduate teacher training program had on elementary teacher candidates’ performance on tests required for licensure.

In a review of the literature, only one study was identified that falls within this line of inquiry (Capraro, Capraro, Parker, Kulm, Raulerson, 2005). The study performed by Capraro et al. investigated the impact grades elementary teacher candidates earned in core mathematics courses had on their scores on the content knowledge and pedagogical content knowledge portions on the licensure test *ExCET*. They found that a positive significant

correlation existed between grades earned in core mathematics courses and the performance on both portions of the *ExCET*.

The findings of the present study indicate that the number of developmental mathematics courses and the level of algebraic integration in the general education mathematics course completed by elementary teacher candidates does not impact their performance on the tests needed for obtaining teaching credentials in Missouri based on the available data information. These findings do not appear to support the findings of Capraro, et al. (2005). However, due to the difference in their study examining the grades earned in core mathematics courses and the present study examining the level of algebraic integration of these courses, this was not unexpected.

In 2012, House Bill 1042 was signed into law (Missouri House of Representative, n.d.). Two parts of this bill were addressed in the present study. The first part addressed is a call for public institutes of higher education to identify and implement “best practices” in developmental education. The second part addressed is a call for the Missouri Department of Higher Education to develop a list of courses that automatically transfer among public college and universities throughout the state. In HB 1042, this list of courses is referred to as the Transfer Course Library.

In regards to “best practices” in developmental education, the findings of the present study do appear to support the results of the study performed by Bahr. According to Bahr (2008), students who were required to complete developmental mathematics course work were not at a disadvantage in reaching levels of academic attainment when compared with those who did not need remediation. Thus, based on the findings of the present study, teacher

candidates who enter college with deficiencies in mathematics are not at a disadvantage for passing the tests needed for obtaining teaching credentials in Missouri.

In regards to development of a statewide Transfer Course Library, the findings of the present study support the addition of general education mathematics courses that de-emphasize algebra, such as finite mathematics. As of fall 2014, the only mathematics courses included in Missouri's Transfer Course Library were calculus I, college algebra and statistics (Missouri Department of Higher Education, n.d.). Recently, the Missouri Mathematics Pathways Taskforce has charged math faculty leaders in the state to adopt courses designed for non-Calculus based programs in addition to introduction to statistics (personal communication, October 30, 2014). According to the findings of the present study, teacher candidates who complete a general education mathematics course that de-emphasized algebra are not at a disadvantage for passing the tests needed for obtaining teaching credentials. Furthermore, these teacher candidates appear to achieve the same level of preparation in the content of the elementary school mathematics curriculum as their counterparts.

Recommendations and Conclusions

Based on the lack of findings of this study, there is a need for further examination of the mathematics preparation of elementary teachers. According to Stith (2001):

I think we would all agree that exists a subset of formal mathematics that all students, regardless of what they choose to do in life, should master. I believe we would also agree that there are certain habits of mind that we want all students to exhibit. (p. 75)

Furthermore, Stith (2001) observed:

I would reiterate, though, that the “what” that is taught is not nearly as important as how the material is taught. I don't underestimate how difficult it will be to change the habits, beliefs, and pedagogical practices of a significant fraction of the teacher workforce. But a fundamental change must occur to reach the point where everyone truly believes that all students can learn mathematics and science. The question is, How do we move beyond the rhetoric? (p. 75)

This question posed by Stith is not new to the educational arena. A body of literature exists that examines the influence various factors have on student achievement in mathematics. Unfortunately, this line of research has not been very successful in identifying key factors. Thus, researchers need to continue in their quest to answer this question. Due to the critical role elementary teachers play in the mathematical learning process combined with the limited number of mathematical courses required for certification, more research on various attributes of the undergraduate mathematics courses completed by these individuals could provide valuable information regarding credentialing for decision makers.

Even though the present study found mathematics course work of elementary teacher candidates did not impact their performance on licensure tests, further research is needed in this line of inquiry. Due to the uniqueness of the university under study, differences due to race and gender were not considered. Since licensure test performances of minority candidates tend to be lower than that of their non-minority peers (National Research Council, 2001b), an extension of the present study may be to examine a group of elementary teacher candidates who provide more diversity in race. In addition, since teacher candidates at the university under study tend to be females, males were underrepresented and need to be included in future research. Furthermore, the present study lacked a mechanism for identifying teacher candidates who were English language or special education learners. Due to the homogeneity of the group of teacher candidates in the present study, a more diverse group might shift some of the results from not being significant to being significant.

According to the National Research Council (2001b), "Initial licensure tests do not provide information to distinguish moderately qualified from highly qualified teacher candidates nor are they designed to test all of the competencies relevant to beginning

practice” (p. 165). Thus, explorations into the impact of the number of developmental mathematics courses and the level of algebraic integration in general education mathematics course completed by pre-service elementary teachers and the effect they have on the achievement of P - 6 students are necessary. Furthermore, examining the grades earned in the developmental mathematics courses and general education mathematics course completed by both teacher candidates and in-service teachers may provide more insight in the mathematical preparation of elementary teachers.

Starting in 2014, new assessments required for obtaining teacher certification in Missouri were implemented (DESE, n.d.). The *College Base* and *Praxis II Content Assessments* were replaced with the *Missouri General Education Assessment* and the *Missouri Content Assessments*, respectively. The *Missouri Educator Profile* and *Missouri Pre-Service Teacher Assessment* were added to provide forms of evidence centering on teacher candidates’ work style and ability to perform various aspects of teaching. On the *Missouri Pre-Service Teacher Assessment*, elementary teacher candidates are instructed to use mathematics as the focus of one of the required tasks. To help in the redesign of teacher education programs, a replication of this study with the new required assessments should be completed as soon as possible. Furthermore, these changes provide new opportunities for investigating the mathematics preparation of individuals preparing to teach at the elementary school level.

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VITA

Kathleen Roy was born on October 30, 1968 in Windsor, Ontario, Canada. With her family, she moved to Troy, Michigan, in 1971 and then to Kansas City, Missouri, in 1980. She graduated from Belton Senior High School in May, 1986. Upon graduating from high school, Ms. Roy began a bachelor's program in mathematics at Avila University in Kansas City, Missouri. She graduated cum laude with a Bachelor of Arts degree in Mathematics with Certification at the Secondary Level in May, 1990.

During the Fall of 1991, Ms. Roy assumed an adjunct instructor position teaching mathematics at Johnson County Community College in Overland Park, Kansas. In the Spring of 1995, she commenced working toward her master's in pure mathematics at University of Central Missouri in Warrensburg, Missouri. She was awarded the Masters of Science degree in Pure Mathematics in May, 1999.

At the beginning of 1998, Ms. Roy moved to Charlotte, North Carolina, where she taught at Southpark Academy, a private high school for at risk-students, for one year. In January of 1999, she accepted a position teaching mathematics at Mitchell Community College in Statesville, North Carolina. During August of 2002, she returned to Kansas City, Missouri, to teach at Avila University, her alma mater. Since 2005, Ms. Roy has served as chairperson of the Mathematics Department at Avila University.

During the Summer of 2005, Ms. Roy started an Interdisciplinary Ph.D. program in curriculum and instruction with the co-discipline of mathematics at the University of

Missouri-Kansas City. After graduating from her Ph.D. program, Ms. Roy plans to continue working at the university level and to pursue research opportunities to further the mathematics education of students at all levels.