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Are Universities Providing Non-STEM Students the Mathematics Preparation Required by Their Programs?: A Case Study of a Quantitative Literacy Pathway and Vertical Alignment from Remediation to Degree Completion

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Abstract

Informed by Gagne's belief in the necessity of prerequisite knowledge for new learning, and Bruner's Spiral Curriculum Theory, the objective of this case study was to explore the postsecondary pathway from remedial mathematics, through one gateway mathematics course, and into the quantitative literacy requirements of various non-STEM programs of study. Particular attention was directed towards analyses of the vertical alignment of course content between: (1) the two consecutive remedial mathematics courses (Beginning Algebra and Intermediate Algebra), (2) the two remedial courses and the gateway course (Fundamentals of College Mathematics), and (3) the gateway course and the quantitative literacy needs of the higher-level coursework in the programs of study. A thorough examination of artifacts and feedback from participants were employed to determine the contents of and prerequisite skills for the mathematics courses. Survey results and extant literature were analyzed to determine the quantitative literacy requirements for later coursework within non-STEM programs of study. Comparison matrices were then utilized to explore the extent of vertical alignment by analyzing overlaps in content from course to course, and by matching prerequisites to course contents throughout the pathway. Evidence of gaps in vertical alignment was discovered, leading to recommendations for changes in course content necessary to fill those gaps.

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I wish to express heartfelt and sincere appreciation to my committee: Dr. Shih, Dr. Olson, Dr. Quinn, Dr. Phanord, and Dr. Warren. Their guidance and input were of great assistance in this endeavor. Thanks also to my fellow graduate students: Amy, Lina, Cat, and Taro. Our discussions regarding the challenges of the process helped put much into perspective. Much appreciation as well to Dr. Lin: who gave the impression that she definitely cared about my progress, and was "in my corner." Last, but certainly not least, I owe much to Dr. William Speer for his critique of my original draft, and his invaluable suggestions for the improvement of my study.

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Chapter 1: Introduction

Extant literature abounds with articles lamenting the need to remediate large numbers of incoming college students who are unprepared for college level coursework in mathematics (Phipps & Merisotis, 2000; Melguizo, Bos, & Prather, 2013; Vandal, 2011). Those students deemed as unprepared, based on SAT/ACT scores or some form of a placement exam, often must complete one or more remedial mathematics courses before they can enroll in a college-level, credit-bearing mathematics course that fulfills their mathematics requirement for graduation. Postsecondary remedial mathematics courses, which do not apply towards graduation requirements, often consist of some combination of Arithmetic, Beginning Algebra, and Intermediate Algebra. The venue for the majority of remedial coursework is the community college, and those four-year colleges and universities that do offer remedial courses usually only offer the Beginning and Intermediate Algebra courses. In many of these institutions, students in remedial courses must earn a grade of C or better, or pass a pass/fail course, in order to move ahead to the next remedial level or enroll in the college-level math class required for their degree.

Depending on the data source, 35% (U.S. Department of Education, 2003) to 75% (Ravitch, 2010) of entering college freshmen need to enroll in remedial mathematics courses. James Dotzler (2003) observes that "many students arrive unprepared by their high schools to succeed in a traditional college-level academic setting" (p. 121). President and CEO of Project Lead the Way, Vince Bertram (2014), states that at "the K-12 level, it is clear that we are failing our students," and cites the USA's placing 30th out of 65 countries in 2012's Programme for International Student Assessment (PISA) rankings as evidence. Until the problem is addressed,

and corrected, at the secondary and primary levels, and if this great nation is to offer higher education to all, then postsecondary institutions must do their best to pick up the baton and continue the race that prepares all students for reaching the finish line known as a college degree. The first step towards this objective, offering unprepared students a chance to get "up to speed," seems to have been accomplished. Approximately 81% of all four-year universities and 100% of community colleges offer courses in remedial mathematics to serve unprepared students (Arendale, 2001).

Unfortunately, there is also an ample supply of literature claiming the remedial courses are not actually preparing students for their college-level math courses and, consequently, the majority of remedial math students do not graduate because they cannot pass their college-level math courses (Waycaster, 2001; Martorell & McFarland, 2009; Schmidt, 2008; Bahr, 2008). Some literature questions whether or not the content of the remedial courses is appropriate for the subsequent college-level coursework that follows (Abou-Sayf, 2008; Adelman, 2005; Asera, 2011; Bettinger and Long, 2009; Boylan, 2011; Bryk and Treisman, 2010; Clyburn, 2013; Johnson, 2007). Furthermore, questions also arise in the literature regarding whether or not the content of the required college-level course following remediation, often referred to as the *gateway* course, contains appropriate content for the quantitative literacy requirements for students who are not in a STEM (science, technology, engineering, and mathematics.) pathway (Bradley, 2011; Merseth, 2011; Schneider, 2001; Hern, 2012; Rotman, 2013; Rutschow and Diamond, 2015).

Problem Statements

The above information leads to four separate problems:

1. An alarming number of students graduate from high school unprepared for college-level mathematics and, therefore, require remediation.
2. A low percentage of students are successful in their remedial math courses.
3. A high percentage of students who are successful in remedial mathematics fail their gateway math course.
4. The alignment of non-STEM gateway courses with the quantitative literacy needs for success in further non-STEM coursework is questionable.

Since the first problem needs to be addressed at the secondary and elementary levels, and problem two has been covered by a plethora of research; this study focused on problems three and four. A major objective of remediation is to prepare students for successful in their gateway course - the course they need for their degree. If a large percentage of students are failing their gateway course after remediation, it seems natural to question whether remediation is actually providing the knowledge and skills that students need for success in those gateway courses. So an overarching question is: Why do a large percentage of successful remedial mathematics students fail their gateway course? If these students have successfully completed a remedial course, they must have learned something. One tends to suspect that what they are learning may not be very helpful for success in their gateway courses. Said another way, there may not be proper vertical alignment between the content of the remedial courses and the gateway courses. Addressing problem four is motivated by the extant literature mentioned above; calling for changes in course content that better aligns with the requirements for non-STEM degree completion.

Purpose Statement and Research Questions

A major question surfacing from the literature is whether or not the content being taught throughout the postsecondary non-STEM mathematics pathway is truly the content that aligns with students' needs; from remediation, through the gateway course, to program completion and graduation. The sparse amount of literature available on this subject gives a negative answer to that question (Johnson, 2007; Bassett & Frost, 2010). In other words, there exists a need to determine the extent to which the remedial mathematics content is vertically aligned with the subsequent college-level mathematics content that follows remediation, and the extent to which the gateway content is aligned with subsequent quantitative coursework required for graduation.

These alignment concerns are the driving forces behind the formulation of the following research questions:

1. To what extent does the content taught in remedial mathematics courses align with the prerequisite needs for success in a non-STEM gateway mathematics course?
2. To what extent does the content taught in a mathematics gateway course for non-STEM degree programs align with the quantitative literacy needs of higher level coursework?

Based on these questions, the purpose of this case study was to explore the content of courses within the postsecondary mathematics pathway regarding course to course vertical alignment from remediation, through the non-STEM gateway mathematics course following remediation, and into the quantitative literacy needs of the various non-STEM programs. At the university serving as the site of this study, the remedial mathematics courses were Math 95 (Beginning Algebra) and Math 96 (Intermediate Algebra); and the gateway mathematics course for most non-STEM programs was Math120 (Fundamentals of College Mathematics). Of the 70 non-

STEM degree programs at the study-site university, 37 listed Math120 as the minimum mathematics requirement for degree completion.

Rationale for Study

There is a real and troubling problem plaguing American colleges and universities. A large percentage of students enter their postsecondary education experience underprepared for college-level mathematics. Consequently, remediation has become standard procedure for growing numbers of college freshmen. In fact, the problem is so ubiquitous, that all community colleges and 81% of four-year colleges offer remedial mathematics programs (Arendale, 2001).

Some troubling numbers. According to the U. S. Department of Education (2003), 22% of entering freshmen enrolled in remedial math courses at postsecondary institutions in 2000. When community colleges were considered separately, this figure jumped to 35%. A Nevada study of 4,653 college freshmen who took a math course their first year of college reported that 37.6% enrolled in remedial mathematics (Fong, Huang, & Goel, 2008). The situation becomes even more troubling when one considers that these numbers may be a grossly understated, as they do not include students who delayed remediation. In one study (Fike & Fike, 2012), the discovery was made that 42% of freshmen in need of remediation delayed enrolling in their remedial courses. The true numbers, therefore, may be closer to those in New York between 2003 and 2008, where: “Three-quarters of the city’s high school graduates who enrolled in … City University of New York were required to take a remedial course” (Ravitch, 2010, p. 89). Another disturbing statistic is that, depending on the school, between 50% and 80% of remedial math students fail to successfully complete their remedial coursework; and therefore, are unable to complete their degree requirements. Research by Attewell, Lavin, Domina, and Levey

concluded that only 30% of remedial mathematics students actually pass their remedial course (2006, p. 912), and a study by Peter Bahr (2008) determined that 75.4% of remedial math students do not remediate successfully (p. 442).

The picture is also bleak for those students who do actually succeed in their remedial courses. An extensive longitudinal study of the Virginia Community College System (Waycaster, 2001), determined that of those students who successfully completed their remedial math courses, only 54% passed their gateway course. Furthermore, the National Conference of State Legislatures (2013) reported that while 58% of non-remedial students earn a bachelor's degree, only 27% of students who take remedial mathematics courses earn their degree. In his study of community college remedial math students, Peter Bahr (2008) concluded that 81.5% of students who successfully complete remediation "do not complete a credential and do not transfer" (p. 442).

To STEM or not to STEM. A major gap in the research exists concerning any information about which math courses students are taking after remediation, but intuition informs that those students who require remediation in high school mathematics probably will not, and most likely should not, seek a degree that requires Calculus, or even Pre-calculus. Hence, it seems logical to conclude that the vast majority of these remedial students are not majoring in Science, Technology, Engineering or Mathematics (STEM) disciplines. In fact, a case study at Eastern Connecticut State University (Johnson, 2007) reported that "the vast majority of students in the Intermediate Algebra course will use almost none of what they actually learn in that course in their college level work in mathematics" (p. 287). Of the 1519 remedial mathematics students from Waycaster's (2001) study of the Virginia Community

College System, only 404 advanced to Pre-calculus; leaving 1115 students taking various other courses such as Technical Math, Math for Allied Health, or Math for Liberal Arts. The Virginia and Connecticut data supply ample evidence to support the logical conclusion that the majority of the remedial math students are not STEM majors and will not be enrolling in Pre-calculus or Calculus, the gateway courses for STEM majors.

Shortage of literature pertaining to course content. Nearly all of the literature discovered regarding remedial mathematics gives only passing reference to the actual content of these remedial math courses. One exception is an interview in which Hunter Boylan (2011) posed the following question to Dr. Paul Nolting, a national expert in assessing individual math learning problems: "The current developmental mathematics curriculum at most institutions includes a combination of arithmetic and introductory and intermediate algebra, thus preparing students to become successful in college algebra. Does this prepare students appropriately for 21^{st} century careers?"(p. 24). Dr. Nolting's response included the following:

> Essentially, the traditional course sequence should match the real math needs of students' majors. For example, there is a high demand for nurses but many colleges and universities require college algebra as an entrance requirement for nursing programs. However, most college algebra skills are not necessary for nursing, and a statistics course would be more appropriate. (p. 26)

The only literature discovered by this author's database search that includes an analysis of the content of remedial math courses and how that content aligns with the content of the gateway courses is a case study by Pete Johnson (2007). Johnson mentions that: "A literature search using the ERIC database found no published studies that investigated both the content of developmental mathematics and college level mathematics courses, and the degree to which one

aligned with the other" (p. 279). In his case study of a university mathematics department, Johnson included "an analysis of the content taught at the developmental level that is actually used by students taking college level mathematics courses" (p. 279). One conclusion Johnson reached was that "the vast majority of students in the Intermediate Algebra course will use almost none of what they actually learn in that course in their college level work in mathematics" (p. 287).

Another study at Jackson State Community College, while exploring the effects of creating modular courses, also briefly touched on the issue of content alignment between remedial and gateway courses (Bassett & Frost, 2010). After separating the content of their three developmental mathematics classes into 12 clearly defined modules, they discovered that:

> Of the 41 courses of study requiring college-level math courses, only 7 required all 12 modules. If students had been required to take all three developmental courses (modules 1 – 12), nearly 80% would be required to master competencies not required for their chosen career. (p. 870)

Who benefits? Whether remedial mathematics classes are offered at a community college or on the campus of a four-year institution, the objective is the same: to prepare students for success in the college-level gateway mathematics courses that are required for their degrees. Consequently, while filling a void in the literature regarding remedial course content by determining if the content is appropriately aligned as a prerequisite for a subsequent gateway non-STEM mathematics course, the information contained in this study will prove beneficial to both two-year and four-year postsecondary institutions; assisting them in the decision-making process concerning the content of their remedial mathematics courses. Furthermore, regarding gateway course content for non-STEM pathways, colleges and universities will also be able to

use the results of this study to inform decisions regarding content changes that might better serve their students. The main potential beneficiaries, however, are those future college students who enroll in remedial mathematics and/or non-STEM gateway mathematics courses at institutions that may have acknowledged the results of this study and implemented content changes accordingly.

Theoretical Framework

The theoretical framework for this study originates from two sources: Gagne's Conditions of Learning Theory that emphasizes the importance of prerequisite knowledge, and the Spiral Curriculum Theory developed by Jerome Bruner.

Conditions of Learning. Gagne (1963) stresses the importance of content alignment in the design of instruction and refers to prerequisite knowledge as "subordinate knowledges" (p. 29). Concerning these subordinates Gagne (1963) observes:

> If a learner attains the objectives subordinate to a higher objective, his probability of learning the latter has been shown to be very high; if he misses one or more of the subordinate objectives, his probability of learning the higher one drops to near zero. In this view, the entire sequence of objectives, one building upon the other until the terminal performance is reached, is considered to be the most important set of variables in the instructional process … failing to achieve a subordinate objective means that the learner effectively 'drops out' of the learning at that point and is unable to acquire the higher-level knowledges. (p.30)

Spiral Curriculum. Bruner (1960) states that “the foundations of any subject may be taught to anybody at any age in some form” (p. 12), provided that the “form” matched the current ability of the learner. He explains his concept of a *spiral curriculum* further:

> To be in command of these basic ideas, to use them effectively, requires a continual deepening of one's understanding of them in progressively more complex forms. … A curriculum as it develops should revisit these basic ideas repeatedly, building upon them until the student has grasped the full formal apparatus that goes with them. (p. 13)

Throughout elementary school, mathematics textbooks appear to adhere to the spiral curriculum concept. These textbooks devote the beginning of each new school year to copious amounts of review from the previous year. But does this really match Bruner's vision? Or, as Robert Jensen (1990) postulates, is the spring *wound too tight*? According to Jensen (1990), "we now typically have curriculum so tightly wound that each year revisits almost all the content of the previous year" (p. 4).

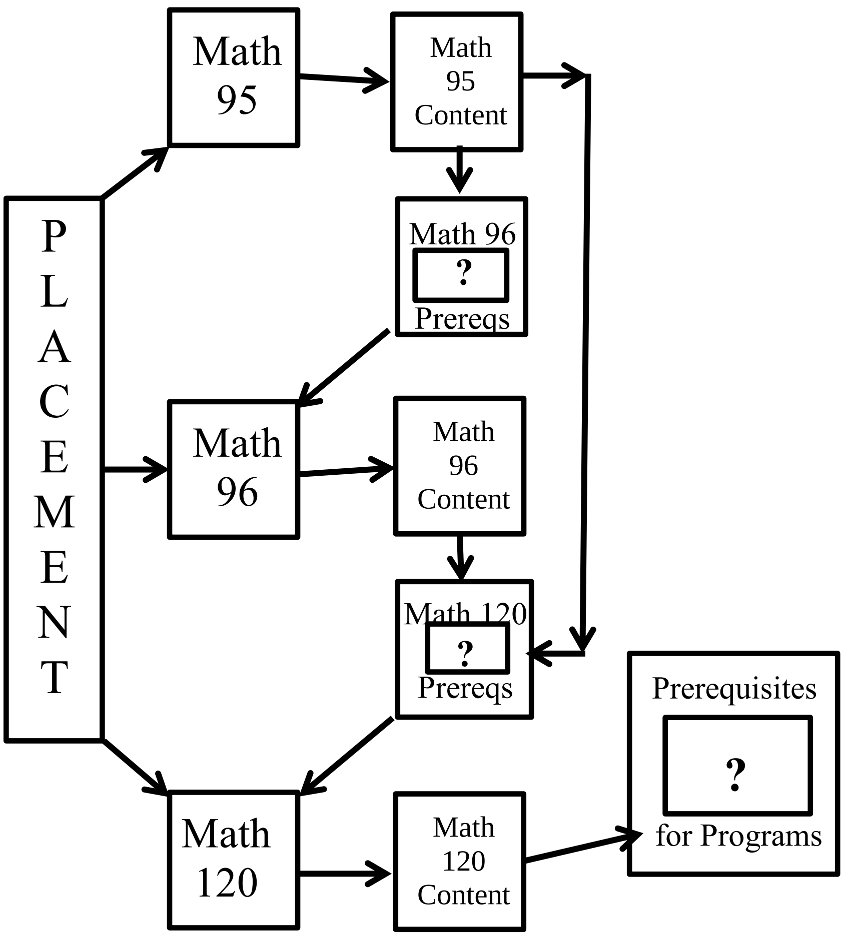
The key to using the spiral curriculum concept effectively is recognizing the necessity of "progressively more complex" as stated in the above Bruner quote. Reviewing material at the exact same level that it was previously presented does not meet this requirement. Harden and Stamper (1999) emphasize that a spiral curriculum does not simply repeat the teaching of a topic, rather: "It requires also the deepening of it, with each successive encounter building on the previous one" (p. 141). They go on to list four features of a spiral curriculum: (1) topics are revisited, (2) there are increasing levels of difficulty, (3) new learning is related to previous learning, and (4) the competence of students increases (p. 141).

Conceptual Framework

The graphic in figure 1 shows the current state of the mathematics pathway for over 50% of the degree programs at the site of this study (37 out of 70). This pathway is for non-STEM

disciplines such as Art, Anthropology, Criminal Justice, Nursing, and Philosophy. (See Appendix A for complete list.) Students are placed into their initial mathematics course based on an assessment score (ACT, SAT, or ALEKS PPL).

Figure 1.1. Pathway for Programs Utilizing Math 120



The question marks in the graphic indicate the focus of this study. Each question mark within a “prerequisite” box represents those prerequisites that may be missing from the course content of the previous course. In other words, those question marks indicate the actual research questions concerning just what is the extent of the alignment between course content and required

prerequisite knowledge for success. Absent from the graphic are the roadblocks in this pathway; namely, the path for students who fail along the way. When students fail any course in this pathway, they usually repeat that course until they are successful, or score high enough on a placement exam to qualify for a higher-level course.

Definition of Key Terms

Remedial mathematics courses. For the purposes of this study, remedial courses are those courses provided for students entering college unprepared for college-level content, containing skills and concepts that were offered at the secondary level. Gabriella Wepner (1987), in a longitudinal study of the remedial math program at a New Jersey college, stated that the "goal of postsecondary mathematics remediation is to sufficiently improve the mathematics skills of remedial students so they can successfully complete college-level mathematics or mathematics dependent courses" (p. 6).

The remedial mathematics courses offered in a remedial mathematics program depends upon the institution. At community colleges, there are usually three levels: Arithmetic, Beginning Algebra, and Intermediate Algebra. Four-year colleges and universities usually offer only the introductory and intermediate algebra courses. The two remedial courses at the university used for the site of this proposed study are Math 95 (Beginning Algebra) and Math 96 (Intermediate Algebra).

Gateway courses. Gateway courses are defined as those courses that are the initial college-level courses in a particular discipline required for degree completion. At the university used for this study, the gateway mathematics courses that follow remedial mathematics courses are

Math120 (Fundamentals of College Mathematics), Math 122 (Number Concepts for Elementary School Teachers), Math 124 (College Algebra), and Math 126 (Pre-calculus 1).

Placement into mathematics courses. Generally, students entering postsecondary institutions are assigned to remedial classes or gateway classes based on ACT/SAT mathematics scores or performance on a mathematics placement test. Scoring above certain cut-scores on any of these assessments places a student into a corresponding level of mathematics instruction. The default course for students enrolling without placement scores or with outdated SAT/ACT scores is the lowest level remedial math course offered. (i.e., the default course at community colleges is usually Arithmetic, and the default at four-year institutions is usually Beginning Algebra.)

Successful course completion. For the purposes of this study, successful completion is defined as earning a grade of C or better in any remedial or gateway course attempted. Earning a grade of C or better qualifies the student for enrollment in the next course in the sequence; either from Arithmetic to Beginning Algebra, Beginning Algebra to Intermediate Algebra, Intermediate Algebra to their gateway course, or the gateway course to any further needed coursework. (Albeit, there are cases where grades as low as D- in a gateway course qualifies toward graduation requirements.)

Quantitative literacy. For the purposes of this study, the definition for quantitative literacy matches that posed by the Association of American Universities & Colleges (*n.d.*):

> Quantitative Literacy (QL) – also known as Numeracy or Quantitative Reasoning (QR) – is a "habit of mind," competency, and comfort in working with numerical data. Individuals with strong QL skills possess the ability to reason and solve quantitative problems from a wide array of authentic contexts and everyday life situations. They understand and can create sophisticated arguments supported by quantitative evidence and they can clearly

> communicate those arguments in a variety of formats (using words, tables, graphs, mathematical equations, etc., as appropriate). (p.1)

Vertical alignment. This study uses the Glossary of Education Reform's (2014) definition of vertical alignment regarding curriculum:

> When a curriculum is *vertically aligned* or *vertically coherent*, what students learn in one lesson, course, or grade level prepares them for the next lesson, course, or grade level. Teaching is purposefully structured and logically sequenced so that students are learning the knowledge and skills that will progressively prepare them for more challenging, higher-level work. (p. 1)

Content comparison matrix. This study defines a content comparison matrix as a two-dimensional array with content topics of one course on the vertical axis and the content topics of a second course on the horizontal axis. If a horizontal topic matches a vertical topic, the intersecting cell is marked with an "X."

Prerequisite comparison matrix. This study defines a prerequisite comparison matrix as a two-dimensional array with exit skills of an earlier course on the vertical axis and the prerequisites for learning the content of a subsequent course on the horizontal axis. If an exit skill matches a prerequisite, the intersecting cell is marked with an "X."

Excessive overlap. This study defines excessive overlap as a result from the comparison of a topic in two courses that indicates the coverage was at the same level of complexity in each course.

Level of complexity. This study defines level of complexity as an indicator of the amount of cognition necessary to learn any given concept, or master any given skill.

Summary

This chapter has served as an introduction to a qualitative case study of a postsecondary quantitative literacy pathway for non-STEM degree programs. An explanation of the motivating factors involved in this study's conception, the research questions, and the theoretical and conceptual frameworks were presented. The next chapter of this dissertation provides a review of the literature pertaining to remedial mathematics, postsecondary quantitative literacy pathways for non-STEM students, and the role of prerequisite knowledge and skills with respect to vertical alignment of content. Subsequent chapters detail the design of the study (chapter 3); the data collection and data analysis (chapter 4); and the findings, conclusions and implications of the study (chapter 5).

Chapter 2: Review of Literature

This literature review details scholarly works on the subject of non-STEM pathways through postsecondary mathematics coursework and the effects of those pathways on degree completion for non-STEM students. A large percentage of students seeking non-STEM degrees are initially placed into remedial mathematics courses (Phipps & Merisotis, 2000; Ravitch, 2010; U. S, Department of Education, 2003), which they must complete successfully before enrolling in a college-level mathematics course. Consequently, this review of literature includes works pertaining to postsecondary remedial mathematics, as it is often the beginning leg of the mathematics pathway to non-STEM degree completion. The databases *Academic Search Premier* and *Educational Resources Information Center* (ERIC) were used to conduct a computerized search for extant literature. After accumulating numerous sources, their references were "mined" for additional pertinent sources. The publication dates of the literature acquired span the years 1984 to 2016, and fall into the following categories:

I. Remedial/Developmental Postsecondary Mathematics
   A. General information
   B. Effectiveness of remediation
   C. Student characteristics
   D. Attempts at program improvement
II. Alternative Pathways/Changes in Content
   A. General examples
   B. Statway/Quantway
III. Prerequisites and Alignment

A. Importance of prerequisites and alignment

B. Determination of prerequisites and alignment

Remedial/Developmental Postsecondary Mathematics

Understandably, since most remedial courses are taken at two-year institutions, the majority of the literature regarding postsecondary remediation focuses on community colleges. Whether students experience remedial courses at a community college or on the campus of a four-year institution, the objective of the remediation program is the same: preparing students for the college level math classes they are required to complete for their degrees. Consequently, the information contained in this review originates from and pertains to both two-year and four-year postsecondary institutions.

General information. The cited percentage of high school graduates entering postsecondary institutions in need of remediation depends on the source; anywhere from 29% (Phipps & Merisotis, 2000) to 75% (Ravitch, 2010). According to the U. S. Department of Education (2003), 22% of entering freshmen enrolled in remedial math courses at postsecondary institutions in 2000. When community colleges were considered separately, this figure jumped to 35%. James Dotzler (2003) observed that “many students arrive unprepared by their high schools to succeed in a traditional college-level academic setting” (p. 121). In response to these numbers, approximately 81% of all four-year universities and 100% of community colleges offer remedial courses in mathematics to serve these unprepared students (Arendale, 2001).

Research by Attewell, Lavin, Domina, and Levey concluded that only 30% of remedial mathematics students actually pass their remedial course (2006, p. 912). Seven years later, Clyburn (2013) confirmed that this statistic had not changed when he stated that “a staggering 70

percent of these students never complete the required mathematics courses" (p. 16). Another study found that only 10% of students placed at the lowest level of remedial mathematics pass the course, and only 18% of those placed at the second level pass (Mireles, Acee, & Gerber, 2014).

Concerning the question about which institutions should be offering remedial courses, Duranczyk and Higbee (2006), in a qualitative research study, found justification for maintaining or instituting remedial courses at four-year colleges, as well as community colleges. In fact, they preferred that students who need them enroll in these remedial courses at four-year schools because those institutions are better prepared to offer additional academic assistance to the students. Surprisingly, some institutions recommend remediation but do not mandate it. A Columbia University study (Jenkins, Jaggars, & Roksa, 2009) discovered that 39% of students who had been recommended, but not required, to enroll in remedial mathematics did not do so.

Effectiveness of Remediation

The National Conference of State Legislatures (2013) reported that while 58% of non-remedial students earn a bachelor's degree, only 27% of students who take remedial mathematics courses earn a degree. Despite these numbers, the message most often conveyed by this subsection of the literature is that, overall remedial classes both at community colleges and at four-year institutions are successful. Bettinger and Long (2009) used a data set of over 28,000 students to compare the success of underprepared students who took remedial courses to those who did not, and concluded that "remediation is an important part of higher education, and it plays a very significant role in attempting to address the needs of the thousands of underprepared students who enter postsecondary institutions each year" (p. 761). Peter Bahr (2008) analyzed

data on 85,894 freshmen enrolled in 107 community colleges and determined that those students who successfully completed remedial math classes "exhibit attainment that is comparable to that of students who achieve college math skill without the need for remediation, and this finding generally holds true even across the various levels of initial math skill deficiency" (p. 442). Gabriella Wepner (1987) reported that 74% of 814 remedial students successfully completed remediation and "findings also showed that students did retain a great deal of the content learned" (p. 8). Additionally, in her report on developmental mathematics programs, Pansy Waycaster (2011) referenced several studies that concluded remedial programs are successful.

Remediation, however, does have its detractors. Attewell, Lavin, Domina, and Levey (2006) exemplify the perspective that "the existence of remediation suggests that some institutions have lowered their standards for admission, and have subsequently 'dumbed down' courses so that underprepared students can make their way through college" (p. 886). Their study of a nationwide cohort of high school students who entered college within eight years of graduation concluded:

> In sum, there was evidence that students who successfully completed remedial coursework in two-year colleges gained from that coursework. There was no such positive evidence about remediation in four-year colleges…
>
> At four-year institutions, taking some remedial courses did modestly lower student chances of graduation, even after we took prior academic preparation and skills into account. Student chances of graduation were reduced between 6% and 7%. (pp. 914-915)

In his attempt to determine if remedial programs are effective, Bahr (2008) warned:

> However, the caveat is large and troubling. Three out of four (75.4%) remedial math students do not remediate successfully…and the academic attainment of these students is abysmal: more than 4 in 5 (81.5%) do not complete a credential and do not transfer. So,

> one must conclude that the answer to the question posed here is "Yes, remediation does work for *some* students," or, perhaps, "*When* remediation works, it works extremely well." (p. 442)

Using Texas data from 1992 to 2000, Martorell and McFarland (2009) found "little indication that students benefit from remediation." An extensive longitudinal study of the Virginia Community College System (Waycaster, 2001), determined that of those students who did successfully complete their remedial math course, only 54% were successful in their Pre-calculus course.

Noting that there is little rigorous research measuring the causal effects of remediation on student outcomes, Crisp and Delgado (2014) used data on 23,090 community college students to determine that "enrolling in a mathematics developmental course was found to significantly decrease the odds that a student would transfer to a 4-year institution within 6 years . . ." (p. 110). However, in this writer's opinion, it appears that these authors have erred in associating correlation with causation. They claimed to have controlled for other variables, but seem to have overlooked the fact that students usually require math remediation because they lack certain knowledge and/or skills, and would naturally be less likely to "persist and transfer" than those students who did not require remediation.

The actual situation regarding the effectiveness of postsecondary mathematics remediation might very well be that of a third view presented in a review of the literature on developmental mathematics' impact on outcomes and persistence (Melguizo, Bos, and Prather, 2011). After their review, these authors concluded that "current evidence on the state of basic skills math in the United States is contradictory and mixed at best" (p. 180).

Student Characteristics

The lack of research regarding the knowledge and attitudes that postsecondary students requiring remediation in mathematics possess prompted research to address the determination of any common characteristics shared by these students (Benken, Ramirez, Li, and Wetendorf, 2015). Using a Likert-type questionnaire completed by a total of 376 students in semester-long Intermediate Algebra courses at California State University Long Beach, the study determined the following shared characteristics:

66% had taken four years of high school math

60% had completed high school courses beyond Algebra II

In general they do not enjoy math (mean = 2.84 on 1-6 scale)

In general they perceived there skill to be average (mean = 3.56 on 1-6 scale)

In general they were fairly confident (mean = 4.03 on 1-6 scale)*

*[This finding appears to be a misinterpretation of the data. The question was; "When my answer to a math problem doesn't match someone else's, I usually assume my answer is wrong" (p. 17). The Likert designations were 1=strongly disagree to 6=strongly agree. The mean of 4.03 indicates that the majority of students seemed to agree with a statement that points to a *lack of confidence*.]

Howard and Whitaker (2011) interviewed successful remedial math students to answer their research question: "What common phenomena accompany students' shift from unsuccessful to successful math experiences" (p. 3)? All students interviewed could remember a specific turning point accompanied by feeling of helplessness when they first experienced a major setback in mathematics. They attributed their later success to new-found motivation and a change in strategies. Strategies cited included: consistent attendance, sitting near the front of

class to avoid distractions, asking questions, diligent completion of homework, and using other resources such as labs and tutors (Howard, & Whitaker, 2011).

A study framed by gender and minority differences in mathematical achievement used data about first-year college students at 24 campuses in 16 states (Hagedorn, Siadat, Fogel, Nora, and Pascarella, 1999). The results showed significant differences in nine variables and were stated as characteristics of non-remedial students (pp. 270-271). Negating those statements generates a list of remedial student characteristics:

(a) Had parents with lower education

(b) Came from families with lower total income

(c) Received less encouragement to go to college

(d) Lived in neighborhoods and attended high schools that were predominantly minority

(e) Reported less time studying in high school

(f) Had lower high school grade point averages

(g) Reported lower levels of cooperative study in college

(h) Perceived the level of college teaching to be lower

(i) Had lower scores on the math achievement test

Another study, examining remedial math students' behavior (Li, et al., 2013), combined ratings for attendance, participation, and homework completion; and employed path analysis to examine the effect of this composite score on course success. The results of that analysis concluded "student course behavior showed a strong direct effect on course success, as well as indirect effects through posttest math knowledge" (p. 19). Also focusing on behavior, a multiple

regression analysis of 382 remedial mathematics students from three Texas colleges determined that "attendance was an important predictor of students' final course grades" (Zientek, Ozel, Fong, and Griffin, 2013).

Similarly, an ethnographic study of 126 developmental math students concluded that attendance and engagement were important characteristics for successful completion of a remedial mathematics course (Smith, O'Hear, Baden, Hayden, and Gorham, 1996). Another study (Wheland, Konet, and Butler, 2003) also determined that poor attendance has a negative effect on success in remedial classes. Surprisingly, many of the students in their study stated that "class attendance is not necessary in order to perform well" (p. 24). Instead, they attributed their lack of success to factors such as instructor incompetence.

Considering another type of student behavior, the incorporation of study strategies into developmental mathematics classrooms was the focus of research using a quasi-experimental method (Mireles, Offer, Ward, and Dochen, 2011) and the Learning and Study Strategies Inventory (LASSI) survey instrument. Introducing lessons in study strategies resulted in significant changes in pre-LASSI versus post-LASSI scores regarding students' attitudes about using resources, time management, self-testing, and other behaviors deemed beneficial for student success.

Recognizing that remedial students often lack motivation and possess math anxiety, one study included analyses on those characteristics (Ironsmith, Marva, Harju, and Eppler, 2003). A shortened version of the Fennema-Sherman Mathematics Attitude Scales was completed by 272 undergraduate students from 17 sections of remedial mathematics at a southwestern university to measure *math anxiety*, *confidence*, *usefulness* and *motivation*. ANOVA results indicated that "all

of these measures were significantly correlated with mathematics performance" (p. 281). Anxiety, motivation, and confidence all had higher correlation with course grades than did SAT score.

According to Fike and Fike (2012), it appears that students should not delay their enrollment into remedial mathematics. They compared groups of non-remedial students, remedial students who enrolled in remedial classes as freshmen, and remedial students who delayed remediation until after their first year of college. They summarize their results from a dataset of 3476 students:

> In other words, those who enrolled in developmental math were the least academically prepared as measured by high school GPA, SAT, and ACT scores; they were less prepared than those who needed but deferred enrollment in developmental math. However, student outcomes (Fall GPA, Fall-to-Spring retention, Fall-to-Fall retention), ranked from highest to lowest were (a) those who passed developmental math and those who were initially college ready [tied], (b) those who deferred enrollment in developmental math, and (c) those who failed developmental math (p. 5).

Another reason for not procrastinating concerns performance in other disciplines that might also benefit from the prerequisite math skills acquired in remediation. Johnson and Kuennen (2004) determined that students who placed into remedial math and delayed taking the remedial coursework had lower performance in introductory microeconomics than those who took the remediation before the microeconomics course.

In his doctoral dissertation, Gonzales (2012) went beyond looking at delayed enrollment and researched the effects of gaps between taking developmental math courses. His purpose was "to determine the correlation among the gaps within the developmental mathematics course sequence to success in college algebra" (p. 11). Participants consisted of 885 first-time-in-college

students that were enrolled at a rural community college. This ex-post-facto correlational study used data from the community college's records over a six-year period. The dependent variable *College Algebra Success* was tested for correlation to the independent variables: *Total Semester Gaps*, *College Algebra Attempts*, *Total Terms Enrolled to College Algebra*, and *Initial Developmental Math Placement*. Analysis determined that there was a statistically significant negative correlation between total gaps (semesters between math courses) and successful completion of College Algebra.

Attempts at Program Improvement

Using technology. Whether or not to use calculators in the remedial mathematics classroom remains an open debate. As MacDonald, Vasquez, and Caverly (2002) explained:

> The debate is over whether or not to utilize technology that is capable of conducting the very skill that the developmental mathematics student is trying to obtain. … For example, graphing calculators are capable of adding fractions and determining the vertex of a parabola. Yet, many traditional developmental mathematics courses include these topics as skill objectives; hence, the controversy over banning calculator use for the students (p. 36).

Using computers as a means to instruct students appears, however, to have overwhelming support. California Polytechnic State University at San Luis Obispo attributed a dramatic improvement in the number of freshmen completing mandatory remedial classes in 1999 to the use of commercial online software to replace traditional classes (Olsen, 2000). Olsen tracked 271 pre-calculus students and determined that students taking the online course "earned 49 percent more A's, B's, or C's [sic] in pre-calculus than did the students who completed algebra course in a traditional classroom" (p. A57). However, since students enrolling in online courses

may be more motivated, more confident, or higher achievers, this data might lose any real statistical significance.

Spradlin and Ackerman (2010) compared the performance of remedial math students enrolled in identical courses that either had supplemental computer assisted instruction, or did not. They concluded that "students perform equally well when receiving traditional classroom instruction and traditional classroom instruction supplemented with computer-assisted instruction" (p. 18). These findings are in agreement with earlier work (Jacobson, 2006; Kinney, 2001) that compared similar groups of students.

The remedial math program at the University of Maryland Eastern Shore was the subject of research to examine student satisfaction and perceived value added of the web-based program Math XL, and examine the impact of Math XL on student performance (Buzzetto-More & Ukoha, 2009). During the fall and spring of 2007-2008, a survey was completed by 692 students enrolled in the remedial course Math 101(a 78% response rate) on the last day of each semester, after the final exams. Longitudinal data was also collected regarding pass/fail percentages and retention rates. Most students thought Math XL was easy to use (63.8%), possessed value as a learning tool (63%), helpful for learning concepts (56%), helped identify what they were doing wrong (58%), and aided them in completing their assignments (53%). However, only 38% said they were satisfied with the system, and female students were 30% more likely to use Math XL. The results seem to indicate that usage of Math XL increases student retention and pass rates, while decreasing withdrawal rates (p. 296). However, since the survey was administered on the final class day of the semester, participants did not include students who had withdrawn or who chose to be absent because they knew they were failing the course. Add to that the fact that 22%

who were present on the last day chose not to participate in the survey, and one might suspect bias in the positive direction.

Acceleration and modularization. Acknowledging that the rationale for modularization “is to accelerate students’ completion of their developmental math requirements,” Ariovich and Walker (2014) investigated the redesign of a three-level remedial mathematics program that produced 14 independent hierarchical modules. Students were placed into an appropriate module via the ACCUPLACER placement test. They were then allowed to proceed at their own pace using computer-based instruction. After mastery of one module, demonstrated by a score of 80% or better on a proctored exam, students were permitted to move to the next module in the sequence. The disappointing results of the redesign showed that the students in the modular courses performed worse (28% pass rate) than students in traditional courses (68%) (p. 48).

Another study, focusing on The Community College of Denver’s FastStart Math program (Jaggars, Hodara, Cho, and Xu, 2015), combined three remedial courses into pairs that could be completed in one semester, rather than the normal two. Results included the finding that “over a 3-year period, FastStart students were 11 percentage points more likely to complete college-level math than their peers in the traditional math sequence” (pp. 16-17).

In 2007, Jackson State Community College redesigned its developmental mathematics program (DSPM):

> The redesign is called SMART (Survive, Master, Achieve, Review, and Transfer) Math, which is Jackson State’s vision of how students experience DSPM in its redesigned format. The objectives include (a) required competencies based on a student’s educational/career goals, (b) mastery of competencies starting at the lowest level of capability, (c) opportunity to progress more quickly (or slowly, if needed), (d) on-demand individualized attention and

> assistance provided to all students, (e) accommodation of varying learning styles, (f) immediate feedback on tests and homework, and (g) more frequent opportunities for successful completion. (Bassett & Frost, 2010)

SMART Math uses 12 modules that encompass all three levels of remediation – three modules for basic math, four modules for elementary algebra, and five modules for intermediate algebra. Assessment places each student into his or her appropriate module at the beginning of each semester and a student must obtain mastery of a module (75% or higher on a posttest) before moving on to the next module of the sequence. Jackson State claims that SMART Math is responsible for a 45% increase in the remedial math pass rate (p. 873).

The University of Maryland College Park separates students identified as needing math remediation into two groups - the bottom 40% and the top. 60% (Adams, 2003). The lowest 40% take a full semester of remediation which meets six hours per week using a computer platform. Another assessment places each of these lower-level students into one of five modules, through which students traverse at their own pace. The top 60% are placed into an *integrated* course (see subsection below) that meets five days per week. Adams stated the results thusly:

> In conclusion we note that the new program prepared the students at least comparably well to the old one. But with the new program hundreds of students (373 students in Fall 2001 alone!) had completed their basic math requirement in one semester, rather than the two that all of these students would have needed under the old program. As a second measure of success of the new program, at the end of the Fall 2001 semester, 80% of the students placed in Developmental Math had either completed or were prepared to complete their math requirement at the beginning of Spring 2002. By contrast in Fall 1999 only 64% of these students were even prepared to move on to their Math requirement in Spring 2000. (p. 12)

Sheldon and Durdella (2010) examined 21,165 enrollment records of a large suburban community college to compare the success rates of compressed (eight-week or six-week) courses and regular length (15-week or 18-week) developmental courses. Their conclusion that the compressed courses garnered greater success appears to be flawed. The analysis was done post facto, so there was no random assignment to the different lengths of courses. It is conceivable that only the more confident, or highly motivated, if not actually better prepared, students would attempt a condensed version of a discipline in which they had previously experienced difficulty.

Approaching acceleration from a unique perspective, the Department of Developmental Mathematics at Utah Valley University designed "Math Pass (MP) as a technology enhanced accelerated remediation tool" (Brinkerhoff and Sorensen, 2015). Students begin the one-credit MP course with a pre-algebra assessment that determines whether they move up. to beginning algebra or receive an in-depth review of pre-algebra. In the five-year period of the study (2005 – 2010), Utah Valley discovered that:

- 48% of students failed the initial Pre-algebra pre-test and began working in pre-algebra material
- 22% of students began working in beginning algebra
- 12% of students began working in intermediate algebra, and
- 11% of students never did any of their work (p. 111-112)

Other findings from the Utah Valley study included: 71% of MP students continued on to take another math course, and 69% of those students passed that next course with a C or better (p. 112). The main conclusion was that "Math Pass does indeed accelerate students through the

developmental mathematics sequence, especially those students who would begin in the lower level courses" (p. 114).

Changes in pedagogy. At New York City College of Technology students are exposed to "self-regulated learning" (Glenn, 2010) that concentrates on encouraging students to learn from their mistakes. Glenn discusses the results:

> There is strong evidence of success. In a rare example of a randomized controlled trial in higher education, researchers based at the Graduate Center of City University of New York found that the developmental-math students at City Tech were significantly more likely to pass the entrance test if they were assigned to a section that used the self-regulated learning technique. (p. A1)

In response to the large number of first year students requiring remedial coursework, Medgar Evers College of The City University of New York initiated a Freshman Year Program (FYP) that emphasized community, orientation to college, awareness strategies, and knowledge of educational and career options (Phoenix, 1990/91). For the FYP sections of remedial mathematics:

> The goal was to create a congenial, stimulating environment that would promote positive attitudes and self-motivation for learning. To that end, four specific strategies were used concurrently: (1) student verbalization and immediate feedback, (2) cooperative learning, (3) a concept/discovery-based approach and (4) creative classroom activities (p. 3).

Even though the results of Phoenix's study were statistically inconclusive, they were promising. The student pass rate (SPR) for the FYP class was 53.3%, while the average SPR for all other sections of the same course was 36.8% (p. 7).

Other studies focused on the instructor's perspective and how different teaching strategies might improve student success in the remedial math classroom. Roberta Dees (1991) conducted a one-semester experiment with 105 of her remedial algebra and geometry students at Purdue University Calumet that used cooperative learning in her treatment groups. At semester's end, Dees concluded:

> Students in the treatment group performed as well as or better than the control group on every outcome measure. … Students in the treatment group generally performed better than students in the control sections on the measures identified as testing the higher cognitive skills (p. 420).

Dees further noted that this is consistent with other literature that claims cooperative learning enhances problem-solving abilities, but has no effect on basic skills.

In her quasi-experimental study, Dianna Hooker (2011) partitioned treatment classes into small groups of 4 – 8 students for cooperative learning. Findings indicated that 43% of treatment students earned a C or better, compared to 35% in the traditional lecture classes. The percentages for perseverance (not dropping out) was 47% for treatment versus 32% for traditional. A similar study used a treatment class that received *reform pedagogy* instruction versus traditional (Smith, et.al, 2015). The authors defined reform pedagogy as instruction wherein the teacher acts as a facilitator who introduces concepts via a problem-solving approach prior to introducing procedures. Results of the study indicated that "students who received reform-oriented instruction demonstrated application skills that were significantly greater than students who received traditional lecture instruction" (p. 135). The authors emphasized that "the gains in application skills in this study did not come at the expense of pass rates or procedural skills" (p.135).

Motivated by a belief that quality teaching is both art and science, Michael Galbraith and Melanie Jones (2006) spent three years interviewing one developmental mathematics instructor. Discussions about research combined with experience resulted in the creation of a list that they named the *Organized Framework for Teaching and Learning:* create a vision, link vision to practice, set climate, understand expectations, plan for learning, connect learning, conceptualize strategies, and celebrate the experience.

Supplemental instruction (SI). Several studies focusing on SI at individual institutions indicate that SI has resulted in significant improvement. The College of Mainland used a student success course to improve their completion rate in remedial mathematics from 46% to 54.8%, (Bradley, 2011). Austin Peay State University allows students identified as needing math remediation to enroll in a college-level math course, but also requires that they enroll in a Structured Learning Assistance (SLA) program (Lorenzetti, 2013). Queensborough Community College and Houston Community College experimented with Learning Communities between 2007 and 2009 (Weissman, et al., 2011). They explained that, "The most basic learning community model co-enrolls a cohort of students in two classes together" (p. 1). Their study involved 2307 remedial mathematics students and:

> The study used an experimental design in which students who were interested and eligible for the courses included in the learning community were randomly assigned to either a program group, whose members were strongly encouraged to participate in the learning communities, or to a control group, whose members received the college's standard services. (p. 1)

The learning community groups at both colleges had higher rates of successful completion of the remedial courses, but no improvements were experienced over the long-term, as there was no increase in "cumulative progress through the math sequence" (p. 3).

Multisite studies also produced positive findings in favor of SI. Wright, Wright, and Lamb (2002) gathered and analyzed data from 90 developmental mathematics courses that investigated a pilot program using an SI instructor that actually participated with students in the treatment classrooms. Even though they did not use any formal statistical tests their analysis showed considerably better grades for the SI students. Zeidenberg, Jenkins, and Calcagno (2007) used student record data from the Florida Department of Education to examine the effects of enrolling in what Florida calls a "student life skills" (SLS) course. Analyzing records from 37,000 community college students, they concluded that "enrollment in an SLS course has a positive marginal effect on a student's chances of earning a credential, persisting, or transferring" (p. 5).

Integrate / eliminate / misc. In attempts to mitigate the need for remedial math courses, some schools are offering early intervention programs. Montgomery County Community College offers a two-week refresher course in math during the summer for remedial students, as well as a peer-tutoring program (Blum, 2007). The University of Southern Indiana experimented with a pilot program named Rapid Review that offered a three-week review of concepts specific to the needs of each individual student as indicated by diagnostic testing (Rodgers, Posler, and Trible, 2011). In 2008, the second year of the program, 63.64% of the Rapid Review students were successful in their college level math course; whereas, only 42.86% of the students who qualified for but chose not to participate in Rapid Review were successful (p. 258).

The Texas program FOCUS (Fundamentals of Conceptual Understanding and Success) allows student to enroll in a college-level mathematics course concurrently with their required remedial mathematics course and receive additional academic support (Mireles, Acee, & Gerber, 2014). Two research questions were posed in the study (p. 28):

1. How does the FOCUS intervention influence student mathematics proficiency?
2. Do students who participate in the FOCUS intervention experience different markers of success as compared to a similar group who did not participate in the intervention?

Participants included 127 students enrolled in College Algebra and the FOCUS intervention in 2010 through 2012, and 1994 students enrolled in College Algebra before FOCUS was implemented (2009 – 2010). The findings indicated that students in the FOCUS group experienced a statistically significant increase from pretest to posttest. Compared to the group of non-FOCUS students, the FOCUS group had a greater percentage of grades A – C, (85% versus 59.3%). Withdrawals were also significantly fewer (6.3%) in the FOCUS group than the control (16.4%) (p. 30).

Community College Research Center (CCRC) at Teachers College conducted a multivariate analysis regarding the results of a Washington State program called I-BEST (Jenkins, Zeidenberg, and Kienzl, 2009). They explained the gist of the model:

> Under the I-BEST model, basic skills instructors and college-level career-technical faculty jointly design and teach college-level occupational courses for adult basic skills students. Instruction in basic skills is thereby integrated with instruction in college-level career-technical skills. … The approach thus offers the potential to accelerate the transition of adult basic skills students to college programs. (p. 2)

The authors concluded that “I-BEST students were more likely to continue into credit-bearing coursework and to earn credits that count toward a college credential” (p. 26).

Southwest Community College (SWCC) decided to change their developmental math courses from three credits to five credits in 1998. Five years later Teresa Woodard and Sexton Burkett (2005) compared success rates from fifteen semesters of the three-credit classes to fifteen semesters of the five-credit classes and found no significant difference. Those results prompted SWCC to return to the three-credit format in 2005. Three years later, the same authors performed a follow-up study using nine five-credit semesters and nine post-2004 three-credit semesters (Woodard and Burkett, 2010). They report the following:

> Since no significant differences were found in the success rates of any of the developmental students when the courses were offered for five credits and then for three credits, we conclude that three-credit courses are just as effective as five-credit courses for developmental math students, reinforcing our previous study. (p. 26)

As another example of integration, in 2005 Middle Tennessee State University (MTSU) chose to completely redesign their developmental mathematics courses (Lucas and McCormick, 2007). Two college level courses, MATH 1010 and Math 1710, were redesigned into Math 1010K and Math 1710K to incorporate remedial material that would “meet the needs of underprepared students” (p. 39). Lucas and McCormick summarize the positive results of the redesign: “Success rates for students in K sections . . . were found to be significantly higher than the success rates of students . . . in non-K sections of these courses” (p. 48).

In another study, Frank Abou-Sayf (2008) analyzed a one-semester suspension of prerequisites in both English and mathematics. His findings included the observation that "the performance of the students who enrolled when prerequisites were not in place was not

significantly different from the performance of students who enrolled in the courses when the prerequisites were in force" (p. 58). Considering the number of limitations to this study, especially no controls for the actual content of the courses in question, the conclusions are suspect. Perhaps the best response to those who argue for the elimination of remedial mathematics is expressed by William Doyle (2012): "Eliminating remediation because many students don't succeed is similar to not performing CPR because so few people are successfully revived" (p. 63).

As an example of what might be considered "fixes" for inhibitors to success, in their ethnographic study of 126 remedial mathematics students, Smith et al. (1996) concluded that five important factors could have a positive influence on the success of remedial students (p. 41):

1. Require mandatory attendance
2. Encourage cooperative learning strategies
3. Decrease class section sizes
4. Choose classrooms conducive for interactions – tables instead of desks
5. Delay math for a semester

Factor five runs counter to the findings of Johnson and Kuennen (2004), and Fike and Fike (2012); but was justified by data suggesting that with more completed hours, students are more invested in their education, which might lead to greater success in their remedial class.

A review of literature by Eades and Moore (2007) on the benefits of enhanced note-taking as a possible fix concluded:

> In our study, referring to the value of the organized note-taking system and encouraging note-taking and utilization enhanced student use. Knowing that a reliable note set was

> available for reference provided a sense of security for students when studying independently or at the college resource center. Overall, survey results and instructor observations revealed this math note-keeping system increased student understanding and motivation (p. 12).

Yet another fix appears to be increased academic intensity. Using data over a nine-year period from Tennessee, William Doyle (2007) concluded that community college students who enrolled in 12 or more hours per semester increased their probability of transfer to a four-year school by more than 11%. Even though Doyle attempts to control for other variables, logic would seem to dictate that claims of causation might be in question. Does enrolling in more courses cause one to be a better student? Or do better students simply take more courses?

In what might qualify as a "thinking outside the box" fix, East Texas State experimented with partitioning the remedial math final exam into sections that correspond to each chapter test (Jones, Yarema, and Windham, 1996). Treatment group students had chapter test scores replaced by any higher final exam score in the appropriate sections. A higher turn-out was noted for the final exam in the treatment group, but the experiment was inconclusive regarding performance results.

The faculty status of remedial mathematics instructors (part time versus full time, and graduate degree or not) was analyzed in a study by David and Renea Fike (2007). Using a sample of 1318 students enrolled in Intermediate Algebra and multiple regression analysis, they determined that faculty employment status "does not have a significant impact on course final grades or course completion status," but faculty education "is associated with course final grades" (p. 6)

Alternative pathways/change in content

Hunter Boylan (2011) posed the following question to Dr. Paul Nolting, a national expert in assessing individual math learning problems: “The current developmental mathematics curriculum, at most institutions, includes a combination of arithmetic and introductory and intermediate algebra, thus preparing students to become successful in college algebra. Does this prepare students appropriately for 21st century careers?” (p. 24). Dr. Nolting’s answer is noteworthy:

> Mathematicians are also asking themselves two curriculum questions: what are the real prerequisite course requirements for noncollege [sic] algebra courses that meet graduation requirements? And, what prerequisite arithmetic/algebra skills are essential to be successful in the next algebra course? Essentially, the traditional course sequence should match the real math needs of students’ majors. For example, there is a high demand for nurses but many colleges and universities require college algebra as an entrance requirement for nursing programs. However, most college algebra skills are not necessary for nursing, and a statistics course would be more appropriate. Are all prerequisite algebra skills – such as dividing polynomials – essential for the next algebra course? Now may be the best time to focus on consistency pertaining to necessary prerequisite developmental algebra courses and algebra skills (p. 26).

Dr. Nolting’s response parallels the opinion of Joe Garofalo (1988), who argued that remedial mathematics programs should teach as much probability and statistics as they do algebra.

Examples of alternate pathways. Many others have shared the above concerns regarding the actual content of the remedial coursework. The Association of American Colleges and Universities (AAC&U) authored an initiative titled "Greater Expectation" (Schneider, 2001) that addressed concerns about quantitative literacy needs for the twenty-first century. Their

recommendations included: "Rethink high school mathematics", "Rethink college quantitative literacy requirements", and "Encourage alternative pathways" (Schneider, 2001, p. 103).

Recognizing that many degree programs require some form of statistics knowledge, the California Acceleration Project implemented a Path2Stats course to replace the standard developmental pathway (Hern, 2012). In a similar vein, a consortium of educators from across the country designed the New Life Program that developed a special course named Mathematical Literacy for College Students (MLCS) that served non-STEM disciplines (Rotman, 2013). The MLCS course was designed to fulfill remedial needs and serve as a gateway course, but might also be the terminal math course for many students.

With the expressed purpose of addressing the math content of remedial courses, the New Mathways Project (NMP) focuses on "the implementation of differentiated math course sequences that are closely aligned with requirements of different academic and eventual career paths" (Rutschow & Diamond, 2015). Creating three different pathways: statistical reasoning, quantitative reasoning, and STEM-prep; the Dana Center implemented the NMP. at community colleges across the state of Texas in 2013 (Rutschow & Diamond, 2015).

Some individual colleges and universities, or state systems, have taken it upon themselves to address the problem of questionable content. One recent example is the Montana University System (MUS). According to their faculty-led Montana Math Pathways Task Force report (2015), the mathematics was not the problem regarding low completion rates; rather, alignment of mathematical content and availability of appropriate pathways stood out as stumbling blocks. The task force published five recommendations:

1. Provide a clear pathway for non-STEM students

2. Evaluate curricular requirements involving College Algebra
3. Strengthen advising processes for math
4. Stronger communication between secondary schools and college
5. Strengthen communication through MUS system (pp. 7 – 12)

As part of their rationale, this task force cited the Mathematical Association of America (MAA): "mathematical science departments should determine the extent to which the goals of courses and programs offered are aligned with the needs of students as well as the extent to which these goals are achieved" (p. 9).

Montgomery County Community College, in Blue Bell, Pennsylvania, increased success rates in 2010 by changing the curriculum for their lowest level remedial mathematics course (Bradley, 2011). They titled their new course *Concepts of Numbers*, included a "history of math" section, and focused on concepts and problem solving rather than having students "memorize arcane rules and then complete exercises based on them" (p. 7).

Collin College uses the Passport Mathematics program that is described as:

> [A]n individualized, flexible, and responsive mathematics program in which learning is self-paced but NOT self-taught. It allows students to receive instruction in the specific segments of mathematics required to advance to their next level by allowing them to focus on the topic(s) they need. … In Passport, the student's learning is predicated on the comprehension of concepts, NOT on a linearly mandated trek through a textbook. (Diaz, 2010)

Statway/Quantway. The above examples have been influenced by, or have collaborated with, the Carnegie Foundation; which has been instrumental in looking for alternative pathways through remediation and into college-level coursework. In 2005, eleven California community

colleges joined in a Carnegie funded endeavor titled Strengthening Pre-collegiate Education in Community Colleges, or SPECC (Asera, 2011). According to Asera:

> The SPECC approach is to map. new pathways through the developmental mathematics landscape in ways that move students directly towards their educational and career goals. Certainly one core pathway would still lead to, and possibly accelerate, progress toward calculus and STEM (Science, Technology, Engineering, and Mathematics) fields. What if there were also pathways for students pursuing careers in allied health or public safety, or planning to transfer and major in humanities or social sciences? Introductory statistics seems to be a useful goal for these students. … Could there also be pathways that would move more directly to statistics or another transfer-level mathematics course that fulfills the quantitative reasoning requirement? (p. 29)

As if anticipating Asera's question, in 2009 the Carnegie Foundation launched Statistics Pathway, or Statway™, which was designed for non-STEM students seeking a college-level statistics course (Bryk & Treisman, 2010; Merseth, 2011; Van Campen, Sowers and Strother, 2013). According to the Van Campen report, "Essentially, Statway students experienced over triple the success rate of students in traditional courses" (p.7). In their Community College Pathways report (Sowers and Yamada, 2015), the Carnegie Foundation described Statway:

> Statway integrates developmental mathematics skills and college-level statistics into a collaborative, problem-focused class. It is a year-long pathway that replaces the traditional algebra sequence and a statistics course, allowing developmental math students to earn college-level credit for statistics in a single academic year. (p. 3)

Recognizing the need for yet another pathway, in 2010, the Carnegie Foundation initiated Quantway™. Merseth (2011) explained:

> Quantway™ represents a non-STEM pathway in which students use numerical reasoning for decision making, argumentation, and sense making about real-world questions and

> problems in contexts of personal, social, and global importance. Quantway™ will require that students use mathematics and numerical reasoning to make sense of the world around them. (p. 33)

In the Sowers and Yamada report cited above, the Carnegie Foundation described Quantway™ as:

> Quantway 1 is a single semester quantitative reasoning course that fulfills the requirements for students' developmental mathematics sequence and prepares them for success in college-level math. Students who succeed in Quantway 1 are then eligible to enroll in Quantway 2, a college credit-bearing quantitative reasoning course, or another college-level course appropriate for their field of study. (p. 3)

Prerequisites and alignment

Importance of prerequisites and alignment. Gagne (1963) stressed the importance of content alignment in the design of instruction and referred to prerequisite knowledge as "subordinate knowledges" (p. 29). Concerning these subordinates Gagne (1963) observed:

> If a learner attains the objectives subordinate to a higher objective, his probability of learning the latter has been shown to be very high; if he misses one or more of the subordinate objectives, his probability of learning the higher one drops to near zero. In this view, the entire sequence of objectives, one building upon the other until the terminal performance is reached, is considered to be the most important set of variables in the instructional process … failing to achieve a subordinate objective means that the learner effectively 'drops out' of the learning at that point and is unable to acquire the higher-level knowledges. (p.30)

According to a recent study regarding the gap between students with prerequisite skills and students without prerequisite skills (Terry, La Harpe, and Kontur, 2016), "prerequisite skills,

rather than some generalized idea of intelligence, is critical to subsequent learning" (p. 34). In their concluding remarks, the authors of the study noted:

> [P]rerequisite performance is a key tool for academic advisors and administrators to identify struggling students early. By ensuring struggling students master key fundamental skills before moving on to advanced courses, we can optimize their future intellectual growth. (p.39)

Much extant literature also addressed questions regarding the necessity of prerequisites for specific coursework: Statistics (Green, Stone, Zegey, and Charles, 2009; Sibulkin and Butler, 2008), Business (Ritchie, Rodriguez, Harrison, and Wates, 2011), Finance (Blaylock and Lacewell, 2008), Economics (Evensky, Kao, Yang, Fadele, and Fenner, 1997; Hoag and Benedict, 2010; Prante, 2016;), Computer Science (Reilly and Tomai, 2014), and Chemistry (Donovan and Wheland, 2009).

Determining prerequisites and alignment. The only literature discovered by this author's database search that included any detailed analysis of the content of remedial mathematics courses and how that content aligns with the content of the college-level courses taken subsequent to remediation was a case study by Pete Johnson (2007). Johnson mentioned that: "A literature search using the ERIC database found no published studies that investigated both the content of developmental mathematics and college level mathematics courses, and the degree to which one aligned with the other" (p. 279). In his study, Johnson included "an analysis of the content taught at the developmental level that is actually used by students taking college level mathematics courses" (p. 279). The conclusion reached in Johnson's study was that "the vast majority of students in the Intermediate Algebra course will use almost none of what they actually learn in that course in their college level work in mathematics" (p. 287).

Although less detailed than Johnson's study, Jackson State Community College (Bassett & Frost, 2010) did address the issue of alignment. They identified specific competencies taught in their three developmental mathematics classes, and separated them into 12 clearly defined modules. The math faculty and faculty from other departments then analyzed the mathematics requirements for subsequent college-level courses. This data was actually a sidebar to the study about their SMART Math program, and details about analysis methods were not given, but the numbers are worth noting:

> Of the 41 courses of study requiring college-level math courses, only 7 required all 12 modules. If students had been required to take all three developmental courses (modules 1 – 12), nearly 80% would be required to master competencies not required for their chosen career. (p. 870)

A study to test a method for determining prerequisites that incorporated all possible pair-wise dependency relationships in a curriculum (Vuong, Nixon, and Towle, 2006) used empirical data from a sample of 20,577 students from 888 schools across the United States. The study compared performances of students who possessed potential prerequisites to those who did not and found that only 43% of potential prerequisites were true prerequisites.

Frank Abou-Sayf and Samir Miari (2007) criticized the use of quantitative techniques for determining prerequisites, stating that "these techniques can often lead to erroneous conclusions" (p.1). Consequently, they advocated the use of qualitative approaches, using special forms such as those used by the California Community College system: (1) Content Review Correlation List Form, and (2) Content Review Matrix (p. 2).

Summary

This chapter has detailed scholarly works pertaining to three areas within postsecondary mathematics: (1) remediation, (2) alternate pathways, and (3) prerequisites and alignment. In the domain of remediation, much of the literature identifies the existence of three major problems: (a) too many students require remediation, (b) too many students fail remediation, and (c) too many students who successfully remediate are not successful in gateway courses. In response to these problems, several studies have attempted to determine whether or not remediation is effective, and have yielded mixed results. Other studies have focused on student characteristics in order to identify possible changes in behavior that might improve performance. Yet another subsection of the remediation domain that appears to have exhibited positive results consists of studies that focused on changes in delivery methods and additional support for remedial students.

Recognizing that there may need to be a change in actual course content in order to prepare students for the quantitative literacy needs of their degree programs, a portion of the literature spotlighted alternative pathways such as Statway, Quantway, Path2Stats, the New Life Program and the New Mathways Project. Even though these alternate pathways are relatively new, so statistical data is lacking, they appear to be improving student pass rates in gateway courses.

Extant literature regarding the importance of prerequisites in general is plentiful; however, there is a paucity of literature within the final domain of this trilogy, prerequisites and alignment, which addresses the content of postsecondary remedial mathematics or gateway mathematics courses. The two studies reviewed that did attempt to analyze alignment between remedial content and gateway prerequisites, although lacking detail, both posited that there was little such alignment. The lack of studies with respect to the alignment of course content in postsecondary

mathematics and quantitative literacy pathways indicates a major gap in the literature, and is one of the driving forces behind this dissertation.

Informed by this review of the literature, and the aforementioned problems that this review has brought to the fore, the following research questions have arisen:

1. To what extent does the content taught in remedial mathematics courses align with the prerequisite needs for success in a non-STEM gateway mathematics course?
2. To what extent does the content taught in a mathematics gateway course for non-STEM degree programs align with the quantitative literacy needs of higher level coursework?

The next chapter of this dissertation presents the design of the study conducted to address these questions.

Chapter 3: Methodology

Informed by Gagne's (1963) emphasis on the importance of the alignment of prerequisite knowledge and skills with higher order knowledge and skills, and Bruner's (1960) Spiral Curriculum theory, the overarching objective of this study was to explore the pathways through the postsecondary mathematics requirements of non-STEM degree programs. Therefore, the focus was on content vertical alignment through the non-STEM pathway from mathematics course to mathematics course, and the vertical alignment between the non-STEM gateway mathematics course and the quantitative literacy needs of the non-STEM degree programs. The design of this study followed a qualitative research approach based on Creswell's (2013) belief that one should "conduct qualitative research because a problem or issue needs to be *explored*" (p. 47).

Research Questions and Purpose Statement

One salient problem emanating from the literature was the fact that an excessive number of students who were successful in remedial mathematics failed their gateway college-level math course. Failure of a gateway course after successful remediation begs the question of whether or not the content of the remedial course actually provides the skills and knowledge that a student needs for success in that gateway course. A second related problem was the apparent dissatisfaction with the content of non-STEM gateway courses, and questions regarding whether or not that content is relevant to the quantitative literacy needs of those degree program pathways that include a non-STEM gateway course. The following research questions were posed to address the above two problems:

1. To what extent does the content taught in remedial mathematics courses align with the prerequisite needs for success in a non-STEM gateway mathematics course?
2. To what extent does the content taught in a mathematics gateway course for non-STEM degree programs align with the quantitative literacy needs of higher level coursework?

Guided by these questions, the purpose of this study was to explore the vertical alignment of the postsecondary mathematics courses in a non-STEM pathway at one university: specifically, the vertical alignment between the two remedial courses (Math 95 and Math 96), the vertical alignment between the remedial courses and the non-STEM gateway mathematics course (Math 120), and the vertical alignment of the gateway course with the quantitative literacy needs of the various programs that include Math 120 in their pathways.

Design of Study

Justification of methodology and methods. The qualitative methodology of this dissertation was that of a case study, utilizing content analysis and grounded theory methods. According to Creswell (2013), a case study design is appropriate; as he explains:

> I choose to view it as a methodology: a type of design in qualitative research that may be an object of study, as well as the product of the inquiry. Case study research is a qualitative approach in which the investigator explores a real-life, contemporary bounded system (a ***case***) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple ***sources of information*** … and reports a ***case description*** and ***case themes***. (p. 97)

The *bounded system* of this case study was the course content within the degree pathway that included the remedial mathematics courses, Math 95 (Elementary Algebra) and Math 96 (Intermediate Algebra), and the gateway college-level mathematics course, Math 120 (Fundamentals of College Mathematics). Although other pathways existed, the Math 120 pathway was chosen because, at the site of this study, 37 of the 70 programs of study offered listed Math 120 as the minimum level course that fulfills the mathematics requirement for degree completion.

This study was composed of three distinct parts: (1) the determination of prerequisite skills and concepts required for success in Math 96, followed by an analysis of the Math 95 content to determine the extent to which Math 95 content meets the prerequisite needs of Math 96; (2) the determination of prerequisite skills and concepts required for success in Math 120, followed by an analysis of the Math 95 and Math 96 content to determine the extent to which they meet the prerequisite needs of Math 120; and (3) the determination of prerequisite skills and concepts required for success in the higher-level courses after Math 120, followed by an analysis of the Math 120 content to determine the extent to which Math120 content meets the prerequisite needs of various degree programs. Said another way, this study determined the mathematical prerequisite needs at different levels through the pathway, and compared those needs with the content of the mathematics course immediately preceding them.

The use of content analysis to address vertical alignment issues is also an appropriate choice. Krippendorff (1989) states his definition: “Formally, content analysis is a research technique for making replicable and valid inferences from data to their context” (p. 403). He continues: “The most obvious sources of data appropriate for content analysis are texts to which

meanings are conventionally attributed" and "the process is objective in that it does not matter who performs the analysis or where and when" (Krippendorff, 1989, p. 404). Also, in his chapter on content analysis, Berg (2008) advocates the use of grounded theory methods to analyze the data collected in a content analysis: "The development of inductive categories allows researchers to link or *ground* these categories to the data from which they derive" (p. 246).

Site and participants. The site of this study was a state university located in the Southwestern United States with a total enrollment of approximately 24,000 students; 83% undergraduates, 55% minorities, and 56% female. The participants in this study included instructors of the mathematics courses (Math 95, Math 96, and Math120). Mathematics instructors consisted of full-time faculty, part-time instructors, and graduate assistants. The ages of the participants ranged from the mid-twenties to the sixties. Inclusion in this purposeful sample was determined using the following criterion: currently teaching Math 95, Math 96 or Math120, or had taught one of those courses within the past year.

Data collection – phase one. Collection of data was divided into two phases. The first phase was designed to gather the necessary data to determine the contents of each mathematics course in the pathway (Math 95, Math 96, and Math 120). Artifacts examined to determine course content included course syllabi, tests, final exams, and textbooks. The syllabi were utilized to identify the textbook sections covered in each course, and content analysis of each textbook was then used to generate a list of topics based on the sub-headings within each section. After analyses using these topics as the unit of analysis, the unit of analysis was further reduced to skills taught within each sub-heading. For validation purposes, these lists of skills, one for each of the three math courses in the pathway, were then cross-referenced against test and exam

questions presented in each of the three courses. At this point, the data collection for phase one analysis (alignment from Math 95 to Math 96, and from Math 96 to Math 120) was complete.

Data collection – phase two. The second phase of data collection was designed to identify the prerequisite quantitative literacy needs for success in coursework that is required for completion of degrees that utilize the Math120 pathway. Data was obtained via access to the results of a survey distributed to faculty and administrators of the university serving as the site of this study (Warren, 2017). In that survey, faculty were asked to rate the current topics presented in Math 120 with respect to the relevance of each topic to their programs. Additional topics not currently present in Math 120, but included in the curriculum of similar courses at other institutions, were also included in the list of topics.

Another question in the survey asked participants to name any topics that were not included in the topics list that they felt should be included in the Math 120 curriculum. Only 2 of 116 respondents answered that question, so the literature was used as a source to finalize the following list of 20 degree program quantitative literacy prerequisites:

1. Math and society
2. Computing with powers of 10
3. Logic
4. Inductive and deductive reasoning
5. Percent and ratio
6. Proportions
7. Fractions
8. Variables

9. Formula manipulations
10. Finance calculations
11. Graphical displays
12. Correlation and regression
13. Sampling and frequency distributions
14. Statistics (central tendency and spread)
15. Normal distributions
16. Validity and reliability
17. Exponential functions
18. Mathematical modeling
19. Excel
20. Dimensional analysis/unit conversions

Data analysis – phase one: the mathematics courses. Analysis of the mathematics courses consisted of two distinct parts: (1) comparison of course contents to identify excessive repetition, or overlap of content, which is evidence of a lack of vertical alignment from course to course in the pathway using topic comparison matrices; and (2) comparison of contents and prerequisites to identify both evidence of the presence and the absence of vertical alignment from course to course in the pathway using skill comparison matrices.

Comparison of course contents to identify excessive overlap. Since any excessive repetition of material from course to course is evidence of a lack of vertical alignment, identification of such incidences was one objective of phase one. The topics lists generated in the data collection to identify the topics contents of each mathematics course (Math 95, Math 96,

and Math 120) were compared via content comparison matrices to identify the presence of any excessive overlap in the contents from course to course. These comparison matrices paired the courses in the following manner:

1. Math 95 and Math 96
2. Math 95 and Math 120,
3. Math 96 and Math 120.

Figure 3.1 displays a small portion of the topics comparison matrix for Math 95 and Math 96.

Recognizing that the Spiral Curriculum Theory (Bruner, 1960) acknowledges that some overlap in content is acceptable, those topics identified as appearing in both courses of a comparison pair were further scrutinized to determine the complexity of coverage within each course. For instance, in figure 3.1, operations with fractions and operations with decimals are marked as appearing in both Math 95 and Math 96. If the complexity increased from course to course, these overlaps were considered to be acceptable and evidence of vertical alignment. If there was no increased complexity from course to course, the overlap was deemed excessive, and evidence of a lack of vertical alignment.

Figure 3.1. Partial Math 95 versus Math 96 Topics Comparison Matrix

TOPICS COMPARISON MATRIX Math95 & Math 96 M A T H 9 5	M A T H 9 6					
	ab-so-lute val-ue	opera-tions with real num-bers	or-der of op-era-tions	lin-ear equa-tions	abso-lute val-ue equa-tions	sol-ving for-mu-las
Powers of 10						
Factors						
Prime factors						
GCF						
LCM						
Simplifying fractions						
Operations with fractions		**X**				
Improper fraction vs mixed						
Operations with decimals		**X**				

Comparison of contents and prerequisites to identify extent of vertical alignment. The skills contents of Math 96 and Math 120 generated in the phase one data collection were both analyzed to determine prerequisite skills and knowledge for success in those two courses. (Note that there was no need to identify the prerequisites for Math 95, as it is the default course for students who could, theoretically, have absolutely no prerequisite knowledge or skills.) Guided by Berg's (2008) opinion that "insights … derive from previous experience with the phenomena" (p. 246), prerequisites for the learning of Math 96 and Math 120 content were identified by the author, based on his experience as a mathematics teacher possessing a Master's degree in Mathematics. Those prerequisites were verified using the opinions of other experienced instructors and Math Department faculty. Once the prerequisites lists were finalized, the decision

was then made to also analyze the alignment of the Math 95 content with the Math 120 prerequisites. Such additional analysis was justified by the fact that some postsecondary institutions require only the Elementary Algebra course (or some indication of that content knowledge) as a prerequisite for their non-STEM gateway math course.

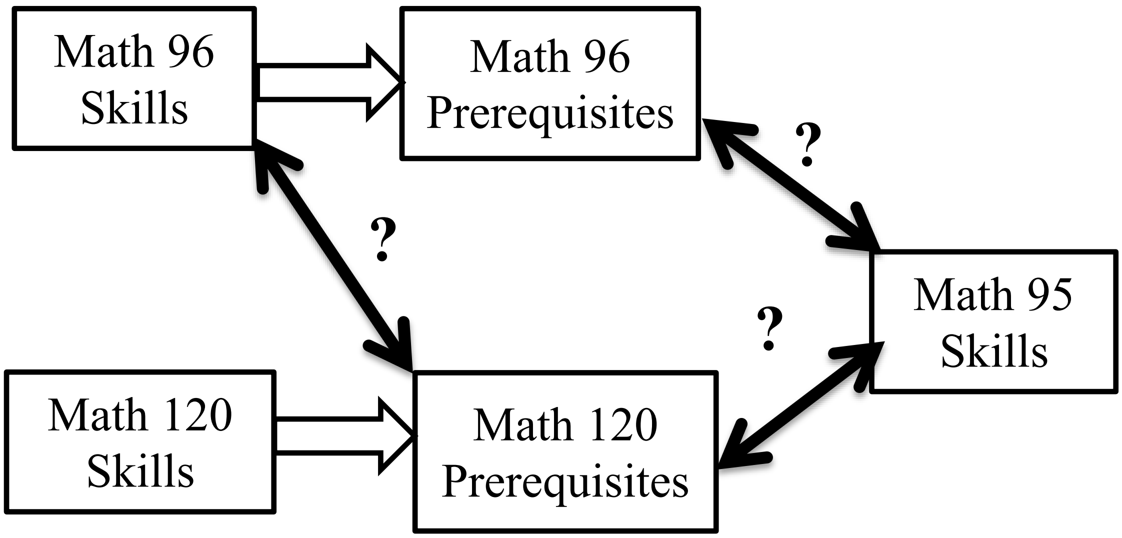
The two lists of skills generated from the Math 95 and Math 96 artifacts were compared separately to the list of prerequisites generated from the list of Math120 content skills. A prerequisite matrix for each of the comparisons between lists (Math 95 versus Math 120, and Math 96 versus Math 120) was created to determine what content from the two remedial courses matched the prerequisites for Math 120. Any skills on the list of prerequisites for the gateway course that were missing from the remedial courses' contents were identified as evidence of the absence of vertical alignment. Furthermore, those skills listed in the Math 95 and Math 96 courses that did not match any of the Math 120 prerequisite skills, were also identified as evidence of the absence of vertical alignment from the remedial course to the gateway Math 120 course. Figure 3.2 shows a small portion of the prerequisites matrix for Math 95 versus Math 120 prerequisites.

Figure 3.2 Partial Prerequisite Matrix

SKILLS PREREQUISITES MATRIX Math 95 Skills vs Math 120 Prereqs	Math 120 Prerequisites						
MATH 95 Exit Skills	operations with whole numbers	using variables	using natural numbers	operations with fractions	operations with decimals	evaluate algebraic expressions	using exponents
define exponent, base, and power							**X**
evaluate expressions with exponents							**X**
eval. numerical expressions using order of operations	**X**						
use variables in expressions		**X**					
define prime and composite numbers							

The two remedial courses were also analyzed in like fashion to determine the extent of the alignment between Math 95 content and Math 96 prerequisites. Figure 3.3 is a graphical representation of the phase one data analysis regarding prerequisites:

Figure 3.3. Phase One Comparisons



Data analysis – phase two: gateway versus programs. The phase two data collection process utilized a survey and literature regarding the quantitative literacy needs of the target non-STEM programs. The list of program prerequisites thus generated (see Table 4.19) were then compared to the Math 120 content exit skills list via a prerequisite comparison matrix (see Appendix B) to determine the extent to which the content of Math 120 matched the program prerequisites. Finally, any content skills on the list of prerequisites for the degree programs that were missing from the Math 120 exit skills list were identified as evidence of an absence of vertical alignment.

Summary

This chapter has reviewed the purpose of the study, reiterated the research questions that were addressed, and detailed the design of the study. The design details included a justification for the qualitative methodology of a case study, and the use of content analysis and grounded theory. Brief descriptions of the two-phase data collection and data analysis procedures were also included in the design details. Complete in-depth descriptions of the data analyses are presented in chapter four.

Chapter 4: Analysis of Data

Research Questions

This dissertation addresses the following two research questions concerning the vertical alignment of mathematics content from course to course within postsecondary non-STEM pathways from remediation to degree completion:

3. To what extent does the content taught in remedial mathematics courses align with the prerequisite needs for success in a non-STEM gateway mathematics course?
4. To what extent does the content taught in a mathematics gateway course for non-STEM degree programs align with the quantitative literacy needs of higher level coursework?

This chapter details the data collection and data analysis of the qualitative study that addressed these questions.

Data Collection and Analysis

Data collection and data analysis were divided into two distinct phases. Phase one focused on the collection and analysis of data to answer research question number one regarding the vertical alignment between the mathematics courses, through remediation and into the gateway course for a non-STEM pathway. Phase two focused on the collection and analysis of data to answer research question number two regarding the vertical alignment between the non-STEM gateway mathematics course and the quantitative literacy needs of various non-STEM degree programs.

Phase one – alignment of the mathematics courses. Phase one data collection and analysis was separated into two different objectives: (a) determining any evidence of excessive

overlap, or redundancy, via the comparison of content between consecutive courses, and (b) determining evidence regarding the presence or absence of prerequisite coverage via the comparison of the content of each mathematics course with the prerequisites of the following mathematics course in the pathway. The two remedial courses at the site of this study are presented using two different formats: (1) a lecture format with computer-based homework assignments (Hawkes), and (2) a completely computer-based format (ALEKS). Both formats cover the same material, but with different textbooks. For this study, the Hawkes format was chosen for collecting and analyzing the data.

The initial unit of analysis chosen to compare the contents of each of the mathematics courses was that of *topic*. A syllabus from each mathematics course (Math 95, Math 96, and Math 120) was used to determine which sections of each textbook were taught. A common syllabus was used by all instructors of the same course; consequently, examination of only one syllabus from each course was necessary. The sections listed in each syllabus were then cross-referenced with the textbooks from each course to determine the actual topic taught. Those textbooks were as follows:

1. Math 95: Introductory Algebra, 6th edition, by D. Franklin Wright (2009)
2. Math 96: Intermediate Algebra, 6th edition, by D. Franklin Wright (2011)
3. Math 120: Thinking Mathematically, 6th edition, by Robert Blitzer (2015)

Topics were identified by section headings and subheadings, resulting in the creation of a list of topics for each course. These topics lists were paired by course and placed into topic comparison matrices to determine if any excessive overlap of content from course to course existed. The two remedial courses, Math 95 and Math 96, were compared; and each of those remedial courses was

compared to the gateway course, Math 120. Although they were not consecutive courses at the time and site of this study, justification for pairing Math 95 and Math 120 stemmed from the fact that they are consecutive courses at other institutions. Consequently, three topics comparison matrices were created:

1. Math 95 was paired with Math 96
2. Math 95 was paired with Math 120
3. Math 96 was paired with Math 120

These topics comparison matrices were used to identify any topics appearing in both paired courses as possible cases of excessive overlap of content from course to course in the pathway. Since Bruner's Spiral Curriculum Theory (1960) accepts some overlap of content, provided that the level of complexity of a topic increases from course to course, each textbook was further analyzed regarding these identified topics to compare the levels of complexity covered within each course. An increased level of the complexity of a topic from course to course was an indication of acceptable overlap. Topics appearing in paired courses that were not presented at an increased level of complexity were considered cases of excessive overlap.

Comparison matrix: Math 95 topics versus Math 96 topics. The matrix used to analyze the possible overlap in content from Math 95 to Math 96 contains 30 topics for Math 95 and 37 topics for Math 96 (see Appendix C). The following eight topics were identified by the matrix as appearing in both Math 95 and Math 96:

1. absolute value
2. operations with real numbers
3. order of operations

4. linear equations
5. linear inequalities
6. systems of linear equations
7. exponents
8. operations with polynomials

Absolute value. The Math 95 textbook devoted approximately one and a half pages in section 1.1 to defining absolute value using the real number line and explaining the process of obtaining the absolute value of real numbers, including six examples of using the number line to obtain the absolute value of various numbers. The Math 96 textbook provided a nearly identical presentation, also utilizing approximately one and a half pages, but included only one example within the explanation. The number of example problems following the explanation of this topic varied considerably: nine for Math 95 and one for Math 96. Despite the difference in the number of examples, the lack of any increase in complexity from Math 95 to Math 96 was evidence that this overlap was excessive. This evidence of excessive overlap from Math 95 to Math 96 is illustrated in table 4.1:

Table 4.1. Detailed Analysis of Overlapping Topic (Absolute Value)

Absolute Value Details of Content	Math 95	Math 96
Definition	X	X
Use of number line	X	X
Examples within explanation	6	1
Examples following explanation	9	4

Operations with real numbers. The Math 96 topic, operations with real numbers, covered six pages and was embedded in a section (1.3) that also included absolute value and order of operations. This topic was matched to two of the Math 95 topics contained in three separate sections: integer operations (1.2 and 1.3; 8 pages) and multiplication and division with real numbers (1.4; 4 pages). Despite the extra pages in Math 95, the presentation of the material was nearly identical in the two textbooks. Consequently, this repetition of content, as displayed in table 4.2, was evidence of excessive content redundancy.

Table 4.2. Detailed Analysis of Overlapping Topic (Operations with Real Numbers)

Operations with Real Numbers: Details of Content	Math 96	Math 120
Addition & subtraction rules for signed numbers	X	X
Multiplication & division rules for signed numbers	X	X
Different symbols for multiplication	X	X
Division by zero explained as undefined	X	X

Order of operations. The Math 95 textbook presented the order of operations in the first section covered in the course (R.1; 3 pages). The textbook for Math 96 placed order of operations in section 1.3 (2 pages), and was also the first section covered in the course. Both textbooks used the acronym PEMDAS as a mnemonic, and admonished giving multiplication and addition priority over division and subtraction, respectively. The additional page in Math 95 was devoted to examples of using incorrect order when evaluating numerical expressions. This nearly identical coverage of the topic indicated excessive overlap of content, as shown in table 4.3:

Table 4.3. Detailed Analysis of Overlapping Topic (Order of Operations)

Order of Operations: Details of Content	Math 96	Math 120
Explanation of the need for rules	X	X
Detailed 4-step rule	X	X
PEMDAS	X	X
Explanation of equal priority of MD & AS	X	X

Linear equations. The Math 95 linear equations section of the textbook (3.1) began by defining equation and solution set, followed by an explanation of using the Addition Principle of Equality and the Multiplication Principle of Equality to solve basic linear equations. Subsequent sections (3.2 and 3.3) introduced multi-step equations, and equations with variables on both sides of the equation. The Math 96 textbook (section 1.4) first defined like and unlike terms, explained how to combine like terms, and then reviewed solving linear equations. The Math 96 textbook also defined the different types of equations: conditional, identity, and contradiction. This additional content in the Math 96 textbook indicated the presence of enough increased complexity in Math 96 to warrant considering this overlap of content acceptable. Table 4.4 illustrates this increased complexity between MATH 95 and MATH 96 regarding linear equations:

Table 4.4. Detailed Analysis of Overlapping Topic (Linear Equations)

Linear Equations: Details of Content	Math 95	Math 96
Definition of equation and solution	X	
Definition of like and unlike terms		X
Step by step solving basic equations	X	X
Definitions of the three types of equation		X

Linear inequalities. The Math 95 linear inequalities section of the textbook (3.4) opened with an explanation of inequality symbols and detailed instructions for solving one-variable linear inequalities that included graphing solutions on a number line. In the Math 95 textbook, open circles indicated exclusion of endpoints of an interval (open), and filled circles, or dots, indicated inclusion of the endpoint (closed). The Math 96 section (1.7) omitted the explanation of inequality symbols, but was identical to the Math 95 content up to and including solving inequalities. Graphing solutions on the number line differed in the Math 96 text by using parentheses instead of open circles and brackets instead of filled circles. The Math 96 section continued with two additional topics not covered in the Math 95 textbook: solving compound inequalities and absolute value inequalities. Also present in Math 96, but not in Math 95, was a table displaying algebraic notation versus interval notation. This analysis of the overlapping content indicated that there was enough increased complexity in Math 96 to conclude that the overlap was acceptable. Table 4.5 illustrates the comparison of MATH 95 and MATH 96 regarding linear inequalities:

Table 4.5. Detailed Analysis of Overlapping Topic (Linear Inequalities)

Linear Inequalities: Details of Content	Math 95	Math 96
Inequality symbols	X	
one-variable inequalities	X	X
graphing solution on number line	X	X
circles for endpoints	X	
parentheses and brackets for endpoints		X
compound inequalities		X
algebraic notation versus interval notation		X

Systems of linear equations. The Math 95 topic *solving systems by graphing* (section 5.1) was matched to the Math 96 topic *systems of linear equations* (section 3.1); however, the Math 96 section also included solving systems using substitution and solving systems using addition. Three pages were devoted to the Math 95 topic and nine pages were utilized in Math 96 to present solving systems via the three different methods. The additional material covered in Math 96 indicated increased complexity and was evidence that this overlap between Math 95 and Math 96 was acceptable. The comparison of MATH 95 and MATH 96 regarding systems of linear equations is illustrated in table 4.6:

Table 4.6. Detailed Analysis of Overlapping Topic (Systems of Linear Equations)

Systems of Linear Equations: Details of Content	Math 95	Math 96
Definitions of consistent, inconsistent, & dependent	X	X
Solving by graphing	X	X
Solving using substitution		X
Solving using addition		X

Exponents. The Math 95 textbook devoted 15 pages (sections 6.1and 6.2) to the topic of exponents, including explanations of all of the rules of exponents. The Math 96 textbook (section 4.1) covers the identical material in nine pages. This lack of increased complexity from Math 95 to Math 96, indicating excessive overlap between Math 95 and Math 96 is illustrated in table 4.7:

Table 4.7. Detailed Analysis of Overlapping Topic (Exponents)

Exponents: Details of Content	Math 95	Math 96
define exponent and base	X	X
product rule	X	X
zero as exponent	X	X
quotient rule	X	X
negative exponents	X	X
power rules	X	X

Operations with polynomials. This Math 96 topic, which was presented in three sections of the textbook (4.2, 4.3, and 4.4), was matched to the Math 95 topic of *add and subtract polynomials*, that was presented in one section (6.4). Additional material in the Math 96 sections included: definitions of monomial, polynomial, and degree of polynomial; classification of polynomials based on degree; multiplication and division of polynomials; and the FOIL method for multiplying two binomials. This evidence of increased complexity leading to acceptable overlap of content from Math 95 to Math 96 is displayed in table 4.8:

Table 4.8. Detailed Analysis of Overlapping Topic (Polynomial Operations)

Operations with Polynomials: Details of Content	Math 95	Math 96
Definition of monomial and polynomial		X
Definition of degree of polynomial		X
Classification based on degree		X
Addition and subtraction explained	X	X
Multiplication and division explained		X
FOIL method explained		X

Comparison matrix: Math 95 topics versus Math 120 topics. The matrix used to analyze the possible overlap in content from Math 95 to Math 120 contains 30 topics for Math 95 and 36 topics for Math 120 (see Appendix D). Three topics appearing in both courses were identified by the matrix:

1. percent
2. mean
3. geometry (area, perimeter, circumference, and volume).

Percent. Both the Math 95 (section R.5) and the Math 120 (section 8.1) textbooks defined percent, explained how to calculate percentages, and explained the process of converting between decimals, fractions and percentages. Additionally, the Math 120 textbook explained the process of calculating percent increase and decrease, and discussed possible abuses of using percentages. Even though much of the content is repeated, the presence of the additional content in Math 120 warranted considering this overlap acceptable. Table 4.9 illustrates this evidence of acceptable overlap between Math 95 and Math 120 regarding percent:

Table 4.9. Detailed Analysis of Overlapping Topic (Percent)

Percent: Details of Content	Math 95	Math 120
definition of percent	X	X
converting decimal to percent	X	X
converting percent to decimal	X	X
converting fraction to percent	X	X
calculating percent of a number & discounts	X	X
calculating percent change (increase & decrease)		X
abuses of percentage claims		X

Mean. Mean was defined as the sum of items divided by the number of items in the Math 95 textbook (section 1.4) using simple algebraic notation. In the Math 120 textbook, mean was defined using sigma notation. Similar basic examples are presented by both textbooks, but Math 120 added a presentation of calculating the mean of frequency distributions. This increased complexity in the Math 120 textbook was evidence of acceptable overlap. Table 4.10 details the comparison of MATH 95 and MATH 120 regarding mean:

Table 4.10. Detailed Analysis of Overlapping Topic (Mean)

Mean: Details of Content	Math 95	Math 120
basic definition (divide sum by number of items)	X	
defined using sigma notation (Σ)		X
basic examples	X	X
calculating for frequency distributions		X

Geometry: area, perimeter, circumference and volume. The sections of each textbook addressing geometric topics were almost identical in content. Math 95 devoted one section (3.8) and seven pages of text to the material. Math 120 imbedded the material within other topics through three sections (10.3, 10.4, & 10.5), and devoted thirteen pages of text to this specific content. Despite these additional pages, there was no increase in the complexity of these topics from Math 95 to Math 120. Table 4.11 illustrates this redundancy regarding geometric topics (area, perimeter, circumference, and volume), and indicates evidence of an excessive overlap of content:

Table 4.11. Detailed Analysis of Overlapping Topic (Geometry)

Geometry: Details of Content	Math 95	Math 120
define radius, diameter, pi	X	X
define area, perimeter, circumference, volume	X	X
calculate areas of triangles & quadrilaterals	X	X
calculate volumes of various solids	X	X

Comparison matrix: Math 96 topics versus Math 120 topics. The matrix used to analyze the possible overlap in content from Math 96 to Math 120 contains 25 topics for Math 96, and 36 topics for Math 120 (see Appendix E). There were two topics appearing in both courses: the Pythagorean Theorem and solving proportions. The Math 96 topic, solving proportions, was not an exact match. It was matched to the Math 120 topic, similar triangles, because proportions appeared as a part of the similar triangles discussion.

Pythagorean Theorem. Regarding content addressing the Pythagorean Theorem, the Math 96 section (4.8) and the Math 120 section (10.2) both led into the topic by defining right triangle, hypotenuse, and leg. Both textbooks then presented the definition of the Pythagorean Theorem, followed by an example of using the theorem to determine the unknown length of one leg of a right triangle. The only notable difference between the two textbooks was that Math 120 had two such examples, and Math 96 had only one. This evidence of excessive overlap is displayed in table 4.12:

Table 4.12. Detailed Analysis of Overlapping Topic (Pythagorean Theorem)

Pythagorean Theorem: Details of Content	Math 96	Math 120
define right triangle, hypotenuse, & legs	X	X
state Pythagorean Theorem	X	X
number of examples (solving for unknown legs)	1	2

Solving proportions. This topic was not an exact match between the two courses: solving proportions from Math 96 was matched to similar triangles from Math 120. Ratio and proportion were defined in Math 96, but not in Math 120. Math 96 also explained the use of the LCM while solving proportions, and the conditions for setting up a proportion; whereas, Math 120 did not. The only notable overlap involved the properties of similar triangles. Consequently, as is displayed in table 4.13, this minor incident of overlapping content was considered acceptable.

Table 4.13. Detailed Analysis of Overlapping Topic (Proportions)

Proportions: Details of Content	Math 96	Math 120
define ratio	X	
define proportion	X	
define similar figures		X
define corresponding parts		X
define similar triangles		X
solve proportion using LCM of denominators	X	
conditions for setting up proportion	X	
properties of similar triangles	X	X

Summary of the results from the comparison matrices. Table 4.14 summarizes the analysis of the topic comparison matrices concerning the overlap of content from course to course through the two remedial mathematics courses (Math 95 and Math 96) and the gateway mathematics course (Math 120). Four of the eight repeated topics from Math 95 to Math 96, one of the three repeated topics from Math 95 to Math 120, and one of the two repeated topics from Math 96 to Math 120 were considered excessively redundant.

Table 4.14. Summary of Topics Comparison Matrices

Topics from Comparison Matrices	Content Overlap	
Math 95 (30) and Math 96 (37)	Acceptable	Excessive
Absolute Value		X
Operations with Real Numbers		X
Order of Operations		X
Linear Equations	X	
Linear Inequalities	X	
Systems of Linear Equations	X	
Exponents		X
Operations with Polynomials	X	
Math 95 and Math 120		
Percent	X	
Mean	X	
Geometry		X
Math 96 and Math 120		
Pythagorean Theorem		X
Solving Proportions	X	

The prerequisite skills matrices. In order to increase the precision in determining if the content of a course that preceded another course in the pathway addressed the prerequisites of the subsequent course, indicating the presence of vertical alignment, the unit of analysis was changed from *topic* to *skill*. Each topic from the topics comparison matrices was subdivided into skills, based on each textbook's content. Skills were defined as: stating properties, defining terms, using formulas, and solving particular types of problems. An exit skills list was generated for each mathematics course in the study: Math 95, Math 96 and Math 120. Exams from each course were also consulted to verify that these lists of skills were covered in each course. Using these skills lists, initial prerequisite skills lists, one for Math 96 and one for Math 120, were determined by the author, drawing on his experience as a teacher of mathematics possessing a

Master's degree in mathematics. Since Math 95 is the default remedial course, there was no need to determine prerequisites for Math 95.

These prerequisite skills lists for Math 96 and Math 120 were then reviewed and edited by instructors from the different courses, as well as other Mathematics Department faculty and the end results were used in the prerequisite skills matrices. These matrices compared the exit skills for each course in the pathway with the prerequisite skills for the course that followed. These pairings of the mathematics courses occurred in the same manner as the topics comparison matrices:

1. Math 95 exit skills were paired with Math 96 prerequisite skills
2. Math 95 exit skills were paired with Math 120 prerequisite skills
3. Math 96 exit skills were paired with Math 120 prerequisite skills

These matrices were used to analyze alignment from two different perspectives: (1) the exit skills from the first courses of each pair that did not match any prerequisites for the second courses and (2) the prerequisites for the second courses of each pair that were not covered in the first courses. Two lists were then generated from each of these three prerequisite skills matrices to determine the extent of the vertical alignment between the contents of the paired courses. Unlike the topics comparison matrices lists that used topics from the lists that were identified by an X showing occurrence in each course, these lists were generated by all cross-sectional cells of each matrix that were empty, indicating no match between exit skills and prerequisites. These lists were:

1. Skills in a lower level course not present in the list of prerequisites for the higher level course, indicating exit skills that were not prerequisite skills

2. Prerequisite skills for a higher level course that were not present in the lower level course, indicating prerequisite needs not covered in the preceding course

Skills prerequisite matrix: Math 95 exit skills versus Math 96 prerequisite skills. The matrix used to analyze the extent of vertical alignment from Math 95 to Math 96 contains 97 exit skills for Math 95 and 26 prerequisite skills for Math 96 (see Appendix F).

Exit skills that were not prerequisite skills. Twenty-one of the Math 95 exit skills did not pair with any Math 96 prerequisite skills. However, eight of these Math 95 exit skills were part of the Math 96 content addressed in the topic overlap analysis, indicating that these skills are introduced as part of the Math 96 curriculum and would not be prerequisites for Math 96. Those remaining 13 Math 95 exit skills that did not match prerequisite skills for Math 96 were:

1. Determining LCM
2. Using tests for divisibility
3. Reading and writing decimals
4. Using operations with decimals
5. Rounding decimals
6. Defining percent and explain use of symbol (%)
7. Changing decimals to percent
8. Changing fractions to percent
9. Identifying natural through real numbers
10. Defining perimeter, area, and circumference
11. Defining radius, diameter, and volume
12. Solving linear equations in two variables

13. Performing operations using scientific notation

Absence of prerequisite skills. The following eight Math 96 prerequisite skills did not match any Math 95 exit skills:

1. Working with restricted values
2. Performing numerical long division
3. Factoring numbers
4. Identifying perfect squares
5. Working with triangles
6. Working with rational expressions
7. Determining roots
8. Identifying numerical squares and cubes

Skills prerequisite matrix: Math 95 exit skills versus Math 120 prerequisite skills. The matrix used to analyze the extent of vertical alignment from Math 95 to Math 120 contains 97 exit skills for Math 95 and 20 prerequisite skills for Math 120 (see Appendix G).

Exit skills that were not prerequisite skills. Forty-six of the 97 Math 95 exit skills did not pair with any Math 120 prerequisite skills. Twenty-eight of those skills pertained to algebraic topics: solving inequalities, lines in the coordinate plane, and manipulations with polynomials. The remaining 18 Math 95 exit skills that did not match any Math 120 prerequisites were:

1. Defining prime and composite numbers
2. Determining numbers to be prime or composite

3. Writing prime factorization of composite numbers
4. Determining the LCM of a set of natural numbers
5. Defining and using inequality symbols
6. Defining and determining absolute values
7. Adding integers
8. Determining if integers are solutions
9. Defining additive inverse
10. Subtracting integers
11. Using alternate symbols to indicate multiplication
12. Multiplying integers
13. Writing and using Polya's steps for problem solving
14. Defining interval of real numbers
15. Defining perimeter, area, circumference
16. Defining radius, diameter, and volume
17. Writing decimal numbers in scientific notation
18. Performing operations using scientific notation

Absence of prerequisite skills. There were three Math 120 prerequisite skills that did not match any Math 95 exit skills:

1. Performing operations with rational expressions
2. Using square roots
3. Creating and using statistical graphs

Skills prerequisite matrix: Math 96 exit skills versus Math 120 prerequisite skills. The matrix used to analyze the extent of vertical alignment from Math 96 to Math 120 contains 58 exit skills for Math 96 and 20 prerequisite skills for Math 120 (see Appendix H).

Exit skills that were not prerequisite skills. Thirty of the Math 96 exit skills did not pair with any Math 120 prerequisite skills. Twenty-two of those exit skills involved algebraic topics: functions, equations, and polynomials. The remaining eight Math 96 exit skills that were not matched to Math 120 prerequisites were:

1. Defining radical sign, radicand, and radical expression
2. Defining square root and cube root
3. Evaluating radical expressions
4. Simplifying square roots and cube roots
5. Defining rational exponents
6. Simplifying and evaluating rational exponent expressions
7. Rationalize radical denominators
8. Identifying the domain of radical functions

Absence of prerequisite skills. There were four of the Math 120 prerequisite skills that did not match any Math 96 exit skills:

1. Performing operations with decimals
2. Using percent
3. Creating and using tables
4. Creating and using statistical graphs

Summary of the results from the prerequisite skills matrices. Table 4.15 summarizes the results of the analysis of the prerequisites skills matrices:

Table 4.15. Summary of Prerequisites Matrices

Paired Courses		Total	Not		Total	Not	
Exit Skills	Prerequisites	Exit Skills	Matched	%	Prerequisites	Matched	%
Math 95	Math 96	97	13	13%	26	8	31%
Math 95	Math 120	97	46	47%	20	3	15%
Math 96	Math 120	59	32	54%	20	4	20%

The percentages in table 4.15 regarding exit skills indicate that 13% of the Math 95 content is not a prerequisite for learning the Math 96 content, 47% of the Math 95 content is not a prerequisite for learning the Math 120 content, and 54% of the Math 96 content is not a prerequisite for learning the Math 120 content. The percentages regarding prerequisites actually covered indicate that 31% of the Math 96 prerequisites are not taught in the Math 95 course, 15% of the Math 120 prerequisites are not taught in the Math 95 course, and 20% of the Math 120 prerequisites are not taught in the Math 96 course.

Instructor interviews and survey. In order to collect additional data for verification of the established prerequisites, and possible identification of additional prerequisites, instructors from the three mathematics courses were interviewed regarding course content and student deficiencies. One instructor from each course was interviewed using a brief (8 questions), semi-structured instrument (see Appendix J). Because of the dual nature of the Math 120 course; namely, playing a role in both phases of this study, a survey was also distributed to multiple Math 120 instructors. Responses to the questions that were most pertinent to this study are presented in the paragraphs that follow.

Math 95 instructor interview. The instructor interviewed for Math 95 had two years' experience teaching that course, as a visiting lecturer. The response to a question asking what percent of students require supplemental instruction was: "between 45 and 55%." The following topics were identified as being part of that supplemental instruction:

1. Long division
2. Fractions
3. Variables
4. Equations
5. Decimals
6. The base-10 number system

Another short list was generated in response to a question asking for non-supplemental content that the instructor would like to add to the current curriculum:

1. More statistics
2. Lines of best fit
3. The normal curve
4. Using Excel

Math 96 instructor interview. The instructor interviewed for Math 96 had two years' experience teaching that course, as a non-tenure track lecturer. The response to the question asking what percent of students require supplemental instruction was: "about 10 or 15%." The following topics were identified as being part of that supplemental instruction:

1. Basic equations

2. Graphing basic lines
3. Knowing what slope is
4. Exponent rules
5. Fractions
6. Decimals
7. Multiplication facts

Response to the question asking for non-supplemental content that the instructor would like to add to the current curriculum generated the following list:

1. Interpretation of graphs
2. Interpretation of what slope is (it means something)
3. Make it more real-world (interesting to students)
4. More applications
5. Work that relates to each student's major (homogenous groups)

Math 120 instructor interview. The instructor interviewed for Math 120 had four years' experience teaching that course as a graduate assistant in the mathematics department. In response to the question as to whether or not she ever needed to cover supplemental material to prepare students for the Math 120 content, her response was: "All the time." The response to the question asking what percent of students require supplemental instruction was: "50 or 60%." The following topics were identified as being part of that supplemental instruction:

1. Order of operations
2. Basic vocabulary
3. Using exponents

4. Solving equations
5. Operations with fractions
6. Operations with decimals
7. Unit conversions

Math 120 instructors' survey. The university schedule of courses was accessed to determine the names of instructors who were teaching Math 120 during the semester in which this study was conducted. Those ten instructors were then emailed a short ten-question survey (see Appendix K). The contents of six completed surveys were analyzed for key words regarding student deficiencies and general opinions about course content. Partial results of that analysis appear in table 4.16:

Table 4.16. Results of Math 120 Instructor Survey

Student Deficiencies	Count
fractions	5
decimals	4
arithmetic	4
percent	1
exponents	1
solving linear equations	1
using formulas	1
probability and statistics	2

When asked what percentages of students require supplemental instruction, the responses ranged from 10% to 50%. Another question of the survey prompted respondents to identify topics or skills that are the most challenging for their Math 120 students. The answers from the four participants who responded to this question follow:

1. With this class and the variety of topics, each topic has a different group of students struggling.
2. Computation, multi step, remembering and using formulas
3. Probability and odds, maybe. Different for every student, though. Sometimes finance, sometimes geometry
4. Probability and statistics

Regarding what topics these instructors felt were important for improving student success, the responses were:

1. Basic skills are important so that students have a basic foundation to build on.
2. Knowing how to study, that it's not enough to read through the lecture notes and say, "Oh I get it."
3. Content could be trimmed to prepare a liberal arts major beyond the mathematics gateway course, which is often a behavioral statistics course. Methods of research could be a productive topic to investigate mathematically for these students.
4. Most students seem to have trouble with the simple reading of the problem, and determining whether an answer makes sense.
5. Self-motivation, responsibility for their own learning.
6. Operations with fractions and decimals.
7. Interpretation and articulation of data.

Overall contributions of instructor interviews and survey. The instructor interviews and the survey revealed no additional prerequisites; rather, they served as verification for the lists of prerequisites established via previous analysis using prerequisite matrices.

Phase two – alignment of the gateway course and the degree programs. The second phase of the data collection and the data analysis addressed the second research question: To what extent does the content taught in a mathematics gateway course for non-STEM programs align with the quantitative literacy needs of higher level coursework? Phase two differed considerably from phase one inasmuch as there was no single textbook to examine for the determination of program prerequisites. Instead, there were 70 different degree programs to consider (see Appendix A): albeit; many of the degrees had similar course requirements.

Survey results. One source of data for phase two was a survey (Warren, 2017) presented to faculty, instructors and advisors at the university that served as the site of this study (see Appendix L for full survey). Several open-ended questions in Warren's survey prompted respondents to describe the level of satisfaction with the current Math 120 course from the instructors' and the students' perspectives, as well as strengths and weaknesses of the current Math 120 course in general. The responses to these questions were coded and analyzed to determine if any generalizations could be drawn regarding the quantitative literacy needs for students in the target programs of this study.

Details of coding open-ended survey responses. Seven pages of printed responses from various open-ended questions in the survey regarding general critiquing of Math 120, including the content of the course and student feedback, were analyzed via grounded theory coding methods. The particular questions from the survey used for this coding were:

Q14: Briefly describe what you consider to be strengths and/or weaknesses in course content.

Q18: Briefly describe at least one strength or weakness to support your level of satisfaction.

Q20: Briefly describe what you have found students identify to be strengths or weaknesses in the course.

Q44: Briefly describe at least one strength or weakness to support your level of satisfaction. (Warren, 2017)

(Note: Although Q18 and Q44 contain identical wording, they were follow-up prompts to two different questions regarding satisfaction levels.)

A total of 126 responses were recorded as open codes and categorized into one of 36 axial codes (see Appendix M). These axial codes were then grouped into five selective codes that indicated the overarching themes of the responses. A list of these themes, the number of open codes constituting each theme, and the number of positive and negative comments is presented in table 4.17:

Table 4.17. Survey Coding Summary (Q14, Q18, Q20, Q44)

Selective Code/Theme	Total Open Codes	Positive	Negative
curriculum	41	10	31
instructor	38	0	38
student preparation	30	1	29
supplemental assistance	4	3	1
administration	3	0	3

Since the theme curriculum had the largest number of appearances in the coding of the responses, the survey question that asked respondents to rate the relevance of curriculum topics as "very relevant," "somewhat relevant," or "not at all relevant" for students in their degree programs was analyzed. Table 4.18 displays the topics that were listed and the data generated:

note that the respondents were not required to address every topic, so the total of the responses for each topic varied somewhat.

Table 4.18. Results from Q24: Of the following topics, identify the relevance you believe they would have for your students.

		Very		Somewhat		Not at All		TTL
1	Percents and Ratios	84%	16	16%	3	0%	0	19
2	Financial calculations	79%	15	16%	3	5%	1	19
3	Set theory and Venn diagrams	35%	6	41%	7	24%	4	17
4	Formula manipulation (when & how to use)	32%	6	68%	13	0%	0	19
5	Displaying & interpreting info graphically	68%	13	26%	5	5%	1	19
6	Points, lines, planes and angles	22%	4	56%	10	22%	4	18
7	Polygons and circles	17%	3	44%	8	39%	7	18
8	Area, perimeter, etc.	28%	5	56%	10	17%	3	18
9	Right triangle trigonometry	21%	4	42%	8	37%	7	19
10	Voting and apportionment	21%	4	68%	13	11%	2	19
11	Sampling and frequency distributions	63%	12	37%	7	0%	0	19
12	Measures of central tendency	63%	12	32%	6	5%	1	19
13	Normal distributions	61%	11	33%	6	6%	1	18
14	Risk ratios	44%	8	39%	7	17%	3	18
15	Validity and reliability	72%	13	17%	3	11%	2	18
16	Mutually exclusive events and odds	37%	7	53%	10	11%	2	19
17	Fundamental counting principle	44%	8	39%	7	17%	3	18
18	Permutations and combinations	31%	5	44%	7	25%	4	16
19	Truth tables	21%	4	53%	10	26%	5	19
20	Conditional statements	26%	5	53%	10	21%	4	19
21	Inductive and deductive reasoning	68%	13	21%	4	11%	2	19

Using the criterion of a "Very" response rate greater than 60%, the following list of eight topics was generated from table 4.18:

1. Percents and ratios
2. Financial calculations

3. Displaying and interpreting information graphically
4. Sampling and frequency distributions
5. Measures of central tendency
6. Normal distributions
7. Validity and reliability
8. Inductive and deductive reasoning

After further analysis of table 4.18, the decision was made to add a ninth topic based on the observation that the response rate for "Not at All" was 0%.

9. Formula manipulations (when and how to use formulas)

A follow-up question in the survey asked respondents to list any additional topics that they felt should be included in the Math 120 content. Unfortunately, there were only two responses to that prompt:

1. I would cut the number of topics
2. Regression and lines of best fit, using technology as a tool (ex, Excel for the statistics and logic topics)

Determination of program prerequisite skills. Due to the reticence of participants in the Warren survey to offer additional mathematics topics that they felt were relevant to their degree programs, an examination of the literature regarding recommended topics to fulfill the mathematical needs of students pursuing non-STEM degrees was performed. Table 4.19 displays the results of that literature examination, along with the above topics that resulted from the survey:

Table 4.19. Results of Survey and Literature Search for Program Prerequisites

Program Prerequisites	a.	b.	c.	d.	e.	f.	g.	h.	i.
math & society		x	x	x	x	x	x	x	
compute with powers of 10		x			x				x
logic		x	x		x		x		
inductive & deductive reasoning	x	x							
percent and ratio	x	x		x		x	x	x	x
proportions		x		x				x	x
fractions	x						x	x	x
variable		x		x	x		x	x	x
formula manipulations	x	x		x	x	x	x	x	x
finance calculations	x				x	x			x
graphical displays	x	x		x	x	x		x	x
correlation & regression	x				x			x	x
sampling & frequency distributions	x					x		x	x
stats (central tendency and spread)	x	x		x	x			x	x
normal distributions	x							x	
validity and reliability	x				x			x	x
exponential functions								x	x
math modeling		x			x	x		x	x
Excel/spreadsheets	x	x		x		x		x	x
dimensional analysis/unit conversion				x				x	x

(a.)Warren Survey (2017), (b.) Task Force on Gateway Math Success (NSHE, 2015), (c.) Origins of Liberal Arts (George, 2010), (d.) Responding to the Recommendations of the Curriculum Foundations Project (Gantner and Haver, 2011), (e.) Quantitative Literacy at Michigan State: Designing General Education Courses(Tunstall, et al, 2016), (f.) Crossroads in Mathematics: Liberal Arts Programs (Cohen, 1995), (g.) 21st Century Quantitative Education (Dingman and Madison, 2011), (h.) New Mathways Project: Student Learning Outcomes for Quantitative Reasoning (Dana Center, 2011), (i.) Carnegie Foundation: Quantway (L. Hosie, personal communication, April 6, 2017)

These 20 degree program prerequisite topics were paired with the Math 120 exit skills in a prerequisites matrix to examine the vertical alignment between Math 120 and the programs.

Matrix: Math 120 exit skills versus program prerequisites. The matrix used to analyze the extent of vertical alignment of the Math 120 content with the program quantitative literacy

prerequisites contained 102 exit skills for Math 120 and 20 prerequisite topics for the degree programs (see Appendix B).

Exit skills that were not prerequisite skills. Sixty-five of the 102 Math 120 exit skills did not pair with any of the program prerequisite topics. The following is a breakdown of those 65 exit skills regarding their mathematical domain:

1. set theory (25)
2. geometry skills (24)
3. probability (16)

Absence of prerequisite skills. The following 12 of the 20 program prerequisite topics did not match any Math 120 exit skills:

1. Math and society
2. Logic
3. Computing with powers of ten
4. Inductive and deductive reasoning
5. Proportions
6. Variables
7. Correlation and regression
8. Validity and reliability
9. Mathematical modeling
10. Excel
11. Dimensional analysis
12. Exponential functions

Table 4.20 summarizes the results of the analysis of the prerequisites skills matrix for the alignment of Math 120 and the non-STEM programs:

Table 4.20. Summary of Math 120 and Programs Alignment

Math 120 Exit Skills	Not Matched to Program Prerequisites	%	Program Prerequisites	Not Matched to Math 120	%
102	65	64%	20	12	60%

Summary of Chapter Four

Chapter four has reiterated the research questions for this dissertation and provided details of the data collection and data analysis processes for the two phases of this case study. The phase-one analysis compared the content of the mathematics courses (Math 95, Math 96, and Math 120) regarding vertical alignment from course to course through the non-STEM mathematics pathway with respect to content redundancy and the coverage of prerequisite skills. The use of topics comparison matrices revealed incidences of excessive overlap of material from course to course. Prerequisite skills were first determined and then compared to the exit skills of earlier courses in the pathway. Skills prerequisites matrices were utilized to determine the percentages of needed prerequisite skills that were lacking in earlier courses, as well as the percentages of skills in previous courses that had no relevance to the prerequisites of courses that followed.

The phase two analysis compared the content of the non-STEM gateway course, Math 120, to the quantitative literacy needs of the degree programs accepting Math 120 as a course fulfilling the mathematics requirement. This comparison yielded the percentage of Math 120

content that did not match prerequisites for the programs, and the percentage of the program prerequisites that were not contained within the Math 120 content. Discussion of the conclusions, implications, and limitations stemming from this analysis are addressed in chapter five.

Chapter 5: Findings, Conclusions and Implications

This culminating chapter serves as a discussion of the preceding four chapters; beginning with a brief summary, and followed by a detailed review of the findings from chapter four. A discussion then ensues regarding the conclusions of the study, how those conclusions addressed the research questions, and the relationship of the conclusions to the literature. Next, a section of this chapter is devoted to the implications of the conclusions, followed by sections addressing the limitations of the study and suggestions for possible future research.

Summary of the Study

This qualitative case study was conducted to address two problems:

1. A large percentage of students who successfully complete postsecondary remedial mathematics courses are not successful in their gateway mathematics course.
2. There is questionable alignment between the contents of the non-STEM gateway course and the quantitative literacy needs of those degree program courses that follow.

In response to these problems, two research questions were formulated:

1. To what extent does the content taught in remedial mathematics courses align with the prerequisite needs for success in a non-STEM gateway mathematics course?
2. To what extent does the content taught in a mathematics gateway course for non-STEM degree programs align with the quantitative literacy needs of higher level coursework?

A review of the literature was partitioned into three major sections: (1) remedial postsecondary mathematics, (2) alternative pathways/changes in content, and (3) prerequisites and alignment. In the domain of remediation, much of the literature identifies the existence of

three major problems: (a) too many students require remediation, (b) too many students fail remediation, and (c) too many students who successfully remediate are not successful in gateway mathematics courses. In response to these problems, several studies have attempted to determine whether or not remediation is effective, and have yielded mixed results. Other studies have focused on student characteristics in order to identify possible changes in behavior that might improve performance. Yet another area of the remediation domain that appears to have exhibited positive results consists of studies that focus on changes in delivery methods and additional support for remedial students.

In recognition of a possible need for changes in the actual course content in order to prepare students for the quantitative literacy needs of their degree programs, a portion of the literature spotlighted alternative pathways such as Statway, Quantway, Path2Stats, the New Life Program and the New Mathways Project. Even though these alternate pathways are relatively new and, therefore, there is lack of statistical data, they appear to be improving student pass rates in gateway courses.

Literature regarding the importance of prerequisites in general was plentiful, but there was a paucity of literature within the domain of prerequisites and alignment that addressed the content of postsecondary remedial mathematics courses or gateway mathematics courses. The two studies reviewed that did attempt to analyze alignment between remedial content and gateway prerequisites, although lacking detail, both posited that there was little such alignment. The lack of studies with respect to the alignment of course content in postsecondary mathematics and quantitative literacy pathways indicated a major gap in the literature.

In order to explore the postsecondary mathematics non-STEM pathway from remediation to degree completion, a qualitative case study design was chosen. Artifacts consisting of course syllabi, exams, and textbooks were utilized to determine the contents, as topics and as exit skills, of the three mathematics courses involved in the study (Math 95, Math 96, and Math 120). Prerequisite skills for the latter two courses (Math 96 and Math 120) were determined via an analysis of that content. The prerequisite quantitative literacy needs of the degree programs that listed Math 120 as a gateway course were determined via the results from a survey and literature sources. Comparison matrices were created and analyzed to identify any excessive topic overlap from course to course in the pathway; and prerequisite matrices were created and analyzed to identify gaps in the alignment of exit skills and prerequisites from course to course, and from Math 120 to the degree programs. The analysis of these matrices generated evidence of the absence of vertical alignment throughout the non-STEM quantitative literacy pathway. Details regarding that evidence are presented in the next section of this chapter.

Findings

Phase one – content overlap of the mathematics courses. The comparison of the Math 95 topics to the Math 96 topics generated a list of eight potential cases of excessive overlap of content:

1. absolute value
2. operations with real numbers
3. order of operations
4. linear equations
5. linear inequalities

6. systems of linear equations
7. exponents
8. operations with polynomials.

Further analysis revealed that the levels of complexity increases enough from course to course for four of the overlapping topics to consider their overlap acceptable; which resulted in a list of four topics that were determined to be evidence of excessive overlap between Math 95 and Math 96:

1. absolute value
2. operations with real numbers
3. order of operations
4. exponents

The comparison of the Math 95 topics to the Math 120 topics generated three potential cases of excessive overlap of content: (1) percent, (2) mean, and (3) geometry. A levels-of-complexity analysis determined that the overlap of mean and percent were acceptable, but the overlap for geometry was not.

The topics comparison matrix for Math 96 and Math 120 identified two potential cases of excessive overlap: (1) Pythagorean Theorem and (2) solving proportions. Solving proportions was presented at a higher level of complexity in Math 120, so the overlap was considered acceptable. The Pythagorean Theorem, however, was presented at identical levels of complexity in both courses, so the overlap was considered excessive.

Phase one – alignment of exit skills and prerequisites. In order to increase the precision in determining vertical alignment, the unit of analysis was changed from topic to skill. Consequently the prerequisite matrices for the mathematics courses compared exit skills and prerequisite skills. One matrix compared Math 95 exit skills and Math 96 prerequisite skills:

1. Thirteen out of 97 (13%) Math 95 exit skills were not prerequisites for Math 96
2. Eight out of 26 (31%) Math 96 prerequisites did not match Math 95 exit skills

Another matrix compared Math 95 exit skills and Math 120 prerequisite skills:

1. Forty-six out of 97 (47%) Math 95 exit skills were not prerequisites for Math 120
2. Three out of 20 (15%) Math 120 prerequisites did not match Math 95 exit skills

A third matrix compared Math 96 exit skills and Math 120 prerequisite skills:

1. Thirty-two out of 59 (54%) Math 96 exit skills were not prerequisites for Math 120
2. Four out of 20 (20%) Math 120 prerequisites did not match Math 96 exit skills

Phase one – instructor interviews and Math 120 survey. In order to collect additional data that could lead to the identification of further needed prerequisites, instructors from the three mathematics courses were interviewed, and Math 120 instructors were surveyed, regarding course content and student deficiencies. All instructors admitted the need to cover supplemental material for many of their students and identified the topics or skills included in that supplemental material. The responses in the interviews and the survey did not uncover any additional prerequisites, but did serve as verification for the prerequisites lists that had been determined via the analyses of the prerequisites matrices.

Phase two – alignment of gateway course and degree programs. The analysis of a survey and literature regarding program prerequisites led to the following list of program prerequisite topics:

1. Math and society
2. Computing with powers of 10
3. Logic
4. Inductive and deductive reasoning
5. Percent and ratio
6. Proportions
7. Fractions
8. Variables
9. Formula manipulations
10. Finance calculations
11. Graphical displays
12. Correlation and regression
13. Sampling and frequency distributions
14. Statistics (central tendency and spread)
15. Normal distributions
16. Validity and reliability
17. Exponential functions
18. Mathematical modeling
19. Excel (spreadsheets)
20. Dimensional analysis

Sixty-five of the 102 Math 120 exit skills (64%) did not pair with any of the program prerequisite topics. Those 65 non-matching exit skills fell into three categories:

1. set theory (25)
2. geometry (24)
3. probability (16)

The following 12 of the 20 program prerequisite topics (60%) did not match any Math 120 exit skills:

1. Math and society
2. Logic
3. Computing with powers of ten
4. Inductive and deductive reasoning
5. Proportions
6. Variables
7. Correlation and regression
8. Validity and reliability
9. Mathematical modeling
10. Excel
11. Dimensional analysis
12. Exponential functions

Conclusions

Phase one and research question one. The phase-one findings addressed research question one regarding the vertical alignment between mathematics courses by analyzing the content of the mathematics courses from two different perspectives: (1) content overlap and (2) the meeting of prerequisite needs.

Comparisons to analyze content overlap from course to course. A summary of the findings regarding content overlap is again presented in table 5.1:

Table 5.1. Summary of Topics Comparison Matrices

Topics from Comparison Matrices	Content Overlap	
Math 95 (30) and Math 96 (37)	Acceptable	Excessive
Absolute Value		X
Operations with Real Numbers		X
Order of Operations		X
Linear Equations	X	
Linear Inequalities	X	
Systems of Linear Equations	X	
Exponents		X
Operations with Polynomials	X	
Math 95 and Math 120		
Percent	X	
Mean	X	
Geometry		X
Math 96 and Math 120		
Pythagorean Theorem		X
Solving Proportions	X	

When content overlap was analyzed, of the 13 topics that were identified as being present in two consecutive courses, seven were found to contain higher levels of complexity, indicating vertical alignment from course to course. The six topics that were found to be cases of excessive overlap were distributed thusly:

(a) between Math 95 and Math 96, 13% (4 out of 30) of the Math 95 topics

(b) between Math 95 and Math 120, 3% (1 out of 30) of the Math 95 topics

(c) between Math 96 and Math 120, 3% (1 out of 37) of the Math 96 topics.

These cases of excessive overlap in content from course to course are indeed evidence of the absence of vertical alignment, but the low percentages seem to be acceptable; especially if the individual topics are scrutinized further. The six overlapping topics were:

1. Absolute value
2. Operations with real numbers
3. Order of operations
4. Exponents
5. Geometry
6. Pythagorean Theorem

Even though it would be ideal to cover these topics at a higher level of complexity when they appear in consecutive courses, their overall importance for learning higher-level concepts warrants covering them again in the pathway, even if at the same level of complexity. Consequently, the conclusion reached by the analysis of the mathematics courses in this pathway

with respect to overlapping content from course to course is that there was only minor evidence of the absence of vertical alignment due to excessive overlap of content.

Comparisons of exit skills to prerequisites from course to course. The analysis regarding prerequisites discovered a considerably different scenario than that of content overlap. Vertical alignment was analyzed by matching exit skills to prerequisites skills from course to course to identify gaps from two directions: (1) from exit skills to prerequisite skills – identifying content in lower course that is not relevant for higher course, (2) from prerequisite skills back to exit skills – identifying missing content in a lower course that should be present in order to meet prerequisite needs of higher course. Table 5.2 summarizes the results of the analysis of exit skills versus prerequisite skills:

Table 5.2. Summary of Prerequisites Matrices

Paired Courses		Total	Not		Total	Not	
Exit Skills	Prerequisites	Exit Skills	Matched	%	Prerequisites	Matched	%
Math 95	Math 96	97	13	13%	26	8	31%
Math 95	Math 120	97	46	47%	20	3	15%
Math 96	Math 120	59	32	54%	20	4	20%

The percentages in table 5.2 regarding exit skills indicate that 13% of the Math 95 content is not a necessary prerequisite for learning the Math 96 content, 47% of the Math 95 content is not a necessary prerequisite for learning the Math 120 content, and 54% of the Math 96 content is not a necessary prerequisite for learning the Math 120 content. The percentages regarding prerequisites indicate that 31% of the Math 96 prerequisites are not taught in the Math 95 course,

15% of the Math 120 prerequisites are not taught in the Math 95 course, and 20% of the Math 120 prerequisites are not taught in the Math 96 course.

The 31% in the last column of table 4.15 indicates that nearly a third of the prerequisites for Math 96 were not taught in the Math 95 course – a course that many students take as a prerequisite for Math 96. Theoretically, students who have not learned 31% of the prerequisites will not possess the required knowledge and skills to learn 31% of the content. If students fail to learn 31% of the Math 96 content, they will most likely be unable to earn a C grade in the course. Based on these findings, the conclusion is that Math 95 and Math 96 are not vertically aligned to an acceptable degree.

With almost half (47%) of the Math 95 exit skills being unnecessary for learning Math 120 content, and 15% of the Math 120 prerequisites not being covered in Math 120, there is considerable lack of alignment between these courses. Also, 32 of the Math 95 exit skills that did not match prerequisites were algebra skills, and since only 3 of the 20 Math 120 prerequisites were algebra topics, one can see why Math 95 was not the prerequisite course for Math 120 at the time and site of this study.

Also, over half (54%) the exit skills of Math 96 are not necessary prerequisites for the learning of the Math 120 content. Twenty-four of those exit skills are algebraic, yet there is very little algebra in Math 120. Even though 16 of the 20 Math 120 prerequisites are included in the Math 96 content, the large percentage of exit skills that do not align with the prerequisites indicates a considerable lack of alignment between these two courses.

The answer to research question one, then, is that the mathematics courses in the non-STEM pathway from remediation to gateway are not aligned to an extent that maximizes student

learning. This conclusion agrees with both Johnson (2007), who stated that most students will use “almost none” of what they learn in Intermediate Algebra in their college-level mathematics class (p. 287), and Basset and Frost (2010), who concluded that of all students taking remedial mathematics courses “80% would be required to master competencies not required for their chosen career” (p. 870).

Phase two and research question two. The phase-two findings addressed research question two regarding the vertical alignment between the non-STEM gateway mathematics course (Math 120) and the quantitative literacy prerequisites for higher-level coursework in non-STEM degree programs. Vertical alignment was analyzed from two different perspectives: (1) identifying exit skills from Math 120 that were not prerequisite skills for the non-STEM degree programs, and (2) identifying non-STEM degree program prerequisites that were absent from the Math 120 content. Table 4.20 summarizes the results of the analysis of the prerequisites skills matrix for the alignment of Math 120 and the non-STEM degree programs:

Table 5.3. Summary of Math 120 and Programs Alignment

Math 120 Exit Skills	Not Matched to Program Prerequisites	%	Program Prerequisites	Not Matched to Math 120	%
102	65	64%	20	12	60%

Twenty quantitative literacy prerequisites were identified for the non-STEM programs, and 12 of the 20 (60%) were not included in the Math 120 curriculum. Furthermore, 64% of the Math 120 exit skills (65 out of 102) were not matched to any of the program prerequisites. These rather large percentages were compelling evidence of an absence of vertical alignment,

and led to the conclusion that, at the time of this study, there was a considerable absence of alignment between the content of Math 120 and the quantitative literacy requirements of the degree programs included in the study. Although no literature was discovered that explicitly supports this conclusion, implicit support is evident within the literature focusing on alternative content for mathematics courses in the non-STEM postsecondary pathways (Schneider, 2001; Hern, 2012; Rotman, 2013; Rutschow & Diamond, 2015).

Implications

Remedial courses. Driven by the importance of learning prerequisite knowledge in order to successfully learn new skills and concepts (Gagne, 1963), the implications of this study are somewhat straight forward. The emphasis on algebraic topics in the remedial courses, although a major requirement for STEM pathways, is incompatible with preparation for a non-STEM gateway mathematics course. The results of this study indicate that, if vertical alignment is accepted as an important objective of course design, course designers should realize that a "one size fits all" approach to course content has not been effective regarding remedial postsecondary mathematics courses. Therefore, attention should be given to the design and implementation of a remedial course, or courses, that are compatible with the non-STEM pathways.

Gateway course. Regarding the non-STEM gateway course (Math 120), it seems puzzling that so much absence of vertical alignment with the non-STEM programs was discovered in a course that should have been specifically designed for those programs. Just as with the remedial courses, the departments involved in course design should seriously consider changing the curriculum of Math 120 to be more compatible with the identified prerequisite needs of the non-STEM programs.

Recommended changes in content. Such changes in curriculum should take a top-down approach by first considering the content of the gateway course, and working backwards to ensure that the remedial courses address the prerequisites of the new gateway course. A possible starting point in Math 120 might be to simply add the missing 60% of the program prerequisites that were identified in this study. That is, add the following topics to Math 120:

1. Math and society
2. Logic
3. Computing with powers of ten
4. Inductive and deductive reasoning
5. Proportions
6. Variables
7. Correlation and regression
8. Validity and reliability
9. Mathematical modeling
10. Excel
11. Dimensional analysis
12. Exponential functions

Naturally, increasing the scope of the content of a course would require eliminating other topics. Since this study revealed that 64% of the current Math 120 content does not address any of the program prerequisites, replacing that 64% with the above topics might solve the problem of the gap in the vertical alignment between Math 120 and the non-STEM programs.

Multiple gateway courses? In agreement with Schneider's (2001) advocacy to develop the "connection of desired capabilities to learning in each student's major, so that study in the major becomes an essential vehicle not only for developing those capabilities but also for learning how to put them to use" (p. 102), the solution may even entail the creation of more than one non-STEM gateway course. The 37 non-STEM programs (see Appendix A) could be grouped according to similar quantitative literacy prerequisite needs. One possible grouping might resemble the following:

Group A (Fine Arts): Art, Dance, Film, Music, and Theatre

Group B (Urban Affairs): Communication, Criminal Justice, Journalism & Media, and Urban Studies

Group C (Education): Early Childhood, Elementary, Secondary , and Special Education

Group D (Socio-Cultural): African-American Studies, Anthropology, Asian Studies, History, Human Services, Gender & Sexuality, Latin-American Studies, Multidisciplinary Studies, Philosophy, Political Science, Sociology, and Social Science

Group E (Languages): English, French, German, Romance Languages, and Spanish

Group F(Nursing): Various Nursing Programs

These groupings are speculative, but it seems there are indeed different groups that might benefit from a non-STEM gateway mathematics course designed specifically for their programs.

New content for remedial course(s). Once the new content of Math 120 has been established, the prerequisites for that newly-designed course, or those newly-designed courses,

should be identified and utilized to determine the content of a new remedial mathematics course, or courses, designated as prerequisite for students who do not place into the new gateway course for their degree program. A new and separate remedial pathway is needed, rather than a change in the current remedial courses, because the current algebra-centered pathway is still necessary for those students in programs that require College Algebra or Pre-calculus as the gateway mathematics experience. For example, if the new content for a non-STEM gateway course does indeed consist of those 20 topics identified by this study, table 5.4 identifies the prerequisites.

Table 5.4. Recommended Math 120 Content and Prerequisites

New Math 120 Content	Prerequisites (New Remedial Content)
math & society	numeracy*
compute with powers of 10	base 10, exponents
logic	numeracy*
inductive & deductive reasoning	numeracy*
percent and ratio	decimals, fractions
proportions	ratios, equations
fractions	integer arithmetic
variable	numeracy*
formula manipulations	order of operations, basic algebra
finance calculations	order of operations, basic algebra
graphical displays	basic graphs
correlation & regression	lines, coordinate plane
sampling & frequency distributions	numeracy*, tables
stats (central tendency and spread)	arithmetic, mean, median, mode
normal distributions	graphs, percent
validity and reliability	numeracy*
exponential functions	functions, exponents, graphing
math modeling	basic algebra, formulas
Excel/spreadsheets	formulas, computer lliteracy
dimensional analysis/unit conversion	operations with fractions

* Numeracy defined here as understanding basic arithmetic operations, magnitudes, and the use of numbers in written text.

Note that where numeracy is listed as a prerequisite in table 5.4, consideration was given to introducing the Math 120 topic at a rudimentary level. The resultant content for remediation prior to the new Math 120 course is displayed in table 5.5:

Table 5.5. Remedial Content Prior to Recommended Math 120

Base 10 and decimals
Number line and magnitudes
Exponents
Order of operations
Fractions and operations
Ratios and percent
Equations and variables
Formulas
Introduction to proportions
Introduction to graphs and tables
Introduction to modeling
Introduction to spreadsheets
Mean, median, mode
Introduction to sampling
Introduction to frequency distributions

Limitations

As with any non-longitudinal study, this study has explored a static "snapshot" in time, and therefore, cannot attest to any changes that may or may not occur over time. The copious amount of literature acknowledging the problems addressed herein, along with the establishment of various alternative pathways, indicate that changes could very well be ongoing during the preparation of this dissertation. Furthermore, the data was collected at a single postsecondary

institution, so the generalizability of this study is limited to institutions that have similar curricula.

It should also be noted that the author has been teaching the remedial courses at the site of this study for several years and may possess certain biases concerning the pathways and course content involved. Although a strident endeavor for total objectivity was a goal of the author throughout the study, it is still possible that some of these biases may have subconsciously influenced the analysis of the data, and the conclusions drawn.

Future Research

Regarding recommendations for further research, the coding results generated by the Warren (2017) survey from questions concerning strengths and weaknesses of the Math 120 course are informative. Table 5.6 illustrates those results:

Table 5.6. Survey Coding Summary (Q14, Q18, Q20, Q44)

Selective Code/Theme	Total Open Codes	Positive	Negative
curriculum	41	10	31
instructor	38	0	38
student preparation	30	1	29
supplemental assistance	4	3	1
administration	3	0	3

The second-most (instructor) and third-most (student preparations) mentioned categories are worthy of future studies. Another question in the survey (Warren, 2017) asked specifically about instructors:

Q39 - It is important who teaches this course (yes/no). If yes, please clarify.

The 39 responses to that question are summarized in table 5.7:

Table 5.7. Survey Coding Summary (Q39)

Selective Code/Theme	total open codes	%
attitude	7	18%
classification	3	8%
communication	7	18%
general concern	3	8%
pedagogy	19	49%

The pedagogy classification in Table 5.7 was used for comments similar to "does not know how to teach." Any comment pertaining to a language barrier was placed into the communication theme, and comments such as "does not seem to care" were placed in the attitude theme. The classification theme referenced comments pointing out that the instructor was a graduate assistant, part time instructor or full time faculty; and the general concern theme was used for statements such as "did not like instructor." Research into any of these themes, and their effect on student success, although beyond the scope of this study, are worthy of future attention.

Additionally, this study focused on a particular non-STEM pathway, but future research into the vertical alignment of the other pathways might point towards beneficial changes in the content of the mathematics courses in those pathways as well.

Summary

The overarching purpose of this study was to explore the content of postsecondary mathematics courses in the non-STEM pathway with respect to vertical alignment from course to course, and to explore the vertical alignment of the gateway mathematics course with respect to the quantitative literacy prerequisites for non-STEM degree programs. An analysis of the contents utilizing topics and skills taught in the three mathematics courses of the pathway thus explored revealed gaps in vertical alignment throughout the pathway, leading to the conclusions that there was indeed substantial evidence of the absence of vertical alignment between courses and between the gateway course and the degree programs. The analysis of the gateway exit skills versus the program quantitative literacy prerequisites uncovered the most egregious cases of missing alignment: 60% of program prerequisites were not addressed by the gateway course (Math 120), and 64% of Math 120 did not address the prerequisite QL needs of the programs.

Concluding that these gaps in vertical alignment should be addressed, recommendations were made to consider course redesign that would create a more vertically aligned non-STEM mathematics pathway. Content for a new non-STEM gateway course, along with remedial content for unprepared students in the pathway was recommended. Course redesigns that improve the vertical alignment throughout the pathway would better serve both students and faculty of those degree programs that utilize the non-STEM pathway.

Appendix A: Degrees Using Math 120

1. African-American Studies
2. Anthropology
3. Art
4. Art History
5. Asian Studies
6. Communication Studies
7. Criminal Justice
8. Dance
9. Early Childhood Education
10. English
11. Film
12. French
13. Gender & Sexuality Studies
14. German
15. Graphic Design & Media
16. History
17. Human Services
18. Jazz Studies
19. Journalism & Media
20. Latin American Studies
21. Multidiscipline Studies
22. Music
23. Music Composition
24. Music Education
25. Music Performance
26. Nursing
27. Philosophy
28. Political Science
29. Romance Languages
30. Secondary Education (Non-STEM)
31. Social Science Studies
32. Sociology
33. Spanish
34. Spanish for Professionals
35. Special Education
36. Theatre
37. Urban Studies

Appendix B: Math 120 Exit Skills versus Program Prerequisites Matrix

PREREQUISITE MATRIX	Non-STEM Program Prerequisite Topicss																			
Math 120 Skills vs Program Prerequisites page 1 Math 120 Exit Skills	math & society	logic	calc with powers of 10	inductive & deductive	% and ratio	proportions	fractions	variables	formula manipulations	finance	graphical displays	correlation & regression	sampling & frequency dist.	descriptive stats	normal distributions	validity & reliability	math modeling	Excel	dimension analysis	exponential functions
use set-builder notation																				
use roster set notation																				
describe sets in words																				
use empty set notation																				
use set element notation																				
represent various sets of natural nos.																				
identify the cardinality of a set																				
identify equivalent sets																				
explain finite versus infinite sets																				
identify equal sets																				
identify subsets of a set																				
use subset symbols																				
identify proper subsets																				
compute number of subsets of finte set																				
use universal set in Venn diagram																				
use Venn diagram for relationship btwn 2 sets																				
describe the complement of a given set																				
determine union of 2 sets																				
determine intersection of 2 sets																				
perform operations with 2 sets																				
use "and" & "or" to identify operations with 2 sets																				
determine cardinality of union of 2 finite sets																				
perform set operations with 3 sets																				
interpret & create Venn diagrams with 3 sets																				
prove equality of sets using Venn diagrams																				
convert btwn fractions and percents					x		x													
convert btwn decimals and percents					x															
convert percents to decimals					x															
solve sales tax applications					x															
solve discount applications					x															
calculate percent increase and decrease					x															
recognize misusage of percents					x															
determine gross income										x										
determine adjusted gross income					x					x										
determine taxable income										x										
calculate federal income tax										x										

PREREQUISITE MATRIX Math 120 Skills vs Program Prerequisites page 2	Non-STEM Program Prerequisite Topicss																			
Math 120 Exit Skills	math & soci-ety	logic	calc with pow-ers of 10	induc-tive & deduc-tive	% and ra-tio	pro-por-tions	frac-tions	var-ia-bles	for-mula man-ipula-tions	finance	gra-phi-cal dis-plays	corre-lation & regres-sion	samp-ling & fre-quency dist.	de-scrip-tive stats	nor-mal dis-tribu-tions	vali-dity & relia-bility	math mo-del-ing	Excel	di-men-sion anal-ysis	expo-nen-tial func-tions
calculate FICA taxes										X										
solve applications involving taxes										X										
calculate simple interest					X				X	X										
calculate future value									X	X										
calculate compound interest									X	X										
calculate present value									X	X										
calculate monthly payments									X	X										
calculate effective annual yield									X	X										
describe points, lines, planes, rays, & segments																				
identify angles and their parts																				
desribe right, acute, obtuse, & straight angles																				
recognize 360 degrees as one rotation																				
describe supplementary & complementary angles																				
describe vertical angles & use to solve problems																				
recognize & describe transversals & angles formed																				
solve problems using equal transversal angles																				
solve problem based on 180 degrees in triangle																				
identify characteristics of triangles																				
solve problems using similar triangles																				
solve problems using Pythagorean Theorem																				
define regular polygon																				
identify polygons using number of sides																				
recognize characteristics of quadrilaterals																				
solve perimeter problems																				
calculate sum of angles in polygons																				
describe andgle requirements for tessalations																				
compute areas of plane regions																				
solve problems using area formulas																				
calculate areas of circles																				
calculate circumferences of circles																				
calculate volumes of 3-D objects																				
calculate surface areas of 3-D objects																				
calculate trig ratios using right triangles					X															
calculate lengths of missing sides triangles via trig									X											
solve applications using trig ratios									X											
use fundamental counting principle for outcomes																				

PREREQUISITE MATRIX

Math 120 Skills vs Program Prerequisites
page 3

Non-STEM Program Prerequisite Topicss

Math 120 Exit Skills	math & society	logic	calc with powers of 10	inductive & deductive	% and ratio	proportions	fractions	variables	formula manipulations	finance	graphical displays	correlation & regression	sampling & frequency dist.	descriptive stats	normal distributions	validity & reliability	math modeling	Excel	dimension analysis	exponential functions
use and evaluate factorials																				
calculate number of possible permutations																				
calculate number of possible combinations																				
recognize appropriate use of perm. versus comb.																				
use combination formula to solve problems																				
define experiment & sample space																				
calculate theoretical probability																				
calculate emperical probability																				
calcualte probability using perm. & comb.																				
calculate probability of event not occurring																				
calculate probability of 1 of 2 events occurring																				
calculate odds																				
i.d. independent, dependent, & mutually exclusive events																				
calculate probability of 2 events occurring																				
calculate conditional probability																				
describe population and random samples													x							
select appropriate sampling technique													x							
use frequency distribution to org. & present data													x							
recognize deceptions in displayed data											x									
calculate mean of a data set														x						
determine median of a data set														x						
calculate the midrange of a data set														x						
calculate the range of a data set														x						
calculate the standard deviation of a data set														x						
recognize characteristics of a normal distribution															x					
apply the 68 - 95 - 99.7 rule															x					
convert raw data to Z-scores															x					
calculate percentiles and quartiles														x						
calculate and innterpret margins of error														x						
recognize and describe skewed data														x						

Appendix C: Math 95 and Math 96 Topics Comparisons Matrix

TOPICS COMPARISON MATRIX Math95 & Math 96	MATH 96																		
MATH 95	absolute value	operations with real numbers	order of operations	linear equations	absolute value equations	formulas	one variable inequalities	compound inequalities	absolute value inequalities	linear functions & notations	graph linear inequalities	systems of linear equations	systems of linear inequalities	exponents	operations with polynomials	factor polynomials GCF	factor by grouping	factor quadratics	special factoring
Powers of 10																			
Factors																			
Prime factors																			
GCF																			
LCM																			
Simplifying fractions																			
Operations with fractions		X																	
Improper fraction vs mixed																			
Operations with decimals		X																	
Percents																			
Mean																			
Plotting on number line																			
Absolute value	X																		
Integer operations		X																	
Mult. & div. with real nos.		X																	
Order if operations			X																
Exponents														X					
Scientific notation																			
Eval. algebraic expressions																			
Distributiveproperty																			
Solving linear equations																			
Area/perimeter/circum./vol.																			
Translate to algebra																			
Univariate linear inequal.							X												
Graphing lines																			
Slopes and intercepts																			
Equations of lines																			
Parallel/perpendicular lines																			
Solve system by graphing																			
Add & subtract polynomials															X				

TOPICS COMPARISON MATRIX Math95 & Math 96	MATH 96																	
MATH 95	polynomial equations	Pythagorean Theorem	quadratic equations	operations with rational expressions	solve rational equations	direct & inverse variation	solve proportions	rational functions	sq. rts.	cube rts	nth rts	rational exponents	operations with radicals	rationalize denominator	solve radical equations	radical functions	sq. root functions	nth root functions
Powers of 10																		
Factors																		
Prime factors																		
GCF																		
LCM																		
Simplifying fractions																		
Operations with fractions																		
Improper fraction vs mixed																		
Operations with decimals																		
Percents																		
Mean																		
Plotting on number line																		
Absolute value																		
Integer operations																		
Mult. & div. with real nos.																		
Order if operations																		
Exponents																		
Scientific notation																		
Eval. algebraic expressions																		
Distributiveproperty																		
Solving linear equations																		
Area/perimeter/circum./vol.																		
Translate to algebra																		
Univariate linear inequal.																		
Graphing lines																		
Slopes and intercepts																		
Equations of lines																		
Parallel/perpendicular lines																		
Solve system by graphing																		
Add & subtract polynomials																		

Appendix D: Math 120 and Math 95 Topics Comparison Matrix

	MATH 95(1)															
TOPICS COMPARISON MATRIX Math 120 vs Math 95 (pg 1) / MATH 120	pow- ers of 10	fac- tors	prime fac- tors	GCF	LCM	Simpli- fying frac- tions	opera- tions with frac- tions	im- proper vs mixed frac- tions	deci- mal opera- tions	per- cents	m e a n	plot on num- ber lline	ab- so- lute val- ue	inte- ger op-- era- tions	op- era- tions with real nos.	order of opera- tions
Representing sets																
Empty set																
Equivalent sets																
Infinite vs finite sets																
Equal sets																
Subsets																
Venn diagrams																
Set operations																
Percents										x						
Taxes																
Simple interest																
Compound interest																
Geometry: Points and lines																
Geometry: Planes and angles																
Similar triangles																
Pythagorean Theorem																
Tessalations																
Perimeter, circumference, & area																
Volume																
Surface area																
Rt triangle Trig																
Fundamental counting principle																
Permutations & combinations																
Theoretical & empirical probability																
Probability-mutually exclusive events																
Odds																
Conditional probability																
Sampling																
Frequency distributions																
Histograms																
Mean, median, mode											x					
Std deviation																
Normal distribution																
Std normal & Z-scores																
Percentiles & quartiles																
Margin of error																

	MATH 95(2)													
COMPARISON MATRIX Math 120 vs Math 95 (pg 2) MATH 120	ex- po- nents	sci- enti- fic no- ta- tion	eval- uate alg. expres- sions	distri- butive pro- perty	solve lin- ear equa- tions	area, peri- meter, circum- fer- ence	English to Algebra	linear ine- qual- ities	graph lines	slopes & inter- cepts	equa- tions of lines	parallel & perpen- dicular lines	solve system by graph- ing	add & Sub- tract poly- no- mials
Representing sets														
Empty set														
Equivalent sets														
Infinite vs finite sets														
Equal sets														
Subsets														
Venn diagrams														
Set operations														
Percents														
Taxes														
Simple interest														
Compound interest														
Geometry: Points and lines														
Geometry: Planes and angles														
Similar triangles														
Pythagorean Theorem														
Tessalations														
Perimeter, circumference, & area						x								
Volume														
Surface area														
Rt triangle Trig														
Fundamental counting principle														
Permutations & combinations														
Theoretical & empirical probability														
Probability-mutually exclusive events														
Odds														
Conditional probability														
Sampling														
Frequency distributions														
Histograms														
Mean, median, mode														
Std deviation														
Normal distribution														
Std normal & Z-scores														
Percentiles & quartiles														
Margin of error														

Appendix E: M ath 120 and Math 96 Topics Comparison Matrix

TOPICS COMPARISON MATRIX page 1 Math120 & Math 96	MATH96											
MATH 120	absolute value	operations with real numbers	order of operations	linear equations	absolute value equations	solving formulas	one variable inequalities	compound inequalities	absolute value inequalities	linear functions & notations	graph linear inequalities	systems of linear equations
Representing sets												
Empty set												
Equivalent sets												
Infinite vs finite sets												
Equal sets												
Subsets												
Venn diagrams												
Set operations												
Percents												
Taxes												
Simple interest												
Compound interest												
Geometry: Points and lines												
Geometry: Planes and angles												
Similar triangles												
Pythagorean Theorem												
Tessalations												
Perimeter, circumference, & area												
Volume												
Surface area												
Rt triangle Trig												
Fundamental counting principle												
Permutations & combinations												
Theoretical & empirical probability												
Probability of mutually exclusive events												
Odds												
Conditional probability												
Sampling												
Frequency distributions												
Histograms												
Mean, median, mode												
Std deviation												
Normal distribution												
Std normal & Z-scores												
Percentiles & quartiles												
Margin of error												

TOPICS COMPARISON MATRIX page 2 Math120 & Math 96	MATH96										
MATH 120	systems of linear inequalities	exponents	operations with polynomials	factor polynomials GCF	factor by grouping	factor quadratics	special factoring	polynomial equations	Pythagorean Theoem	quadratic equations	operations with rational expressions
Representing sets											
Empty set											
Equivalent sets											
Infinite vs finite sets											
Equal sets											
Subsets											
Venn diagrams											
Set operations											
Percents											
Taxes											
Simple interest											
Compound interest											
Geometry: Points and lines											
Geometry: Planes and angles											
Similar triangles											
Pythagorean Theorem									X		
Tessalations											
Perimeter, circumference, & area											
Volume											
Surface area											
Rt triangle Trig											
Fundamental counting principle											
Permutations & combinations											
Theoretical & empirical probability											
Probability of mutually exclusive events											
Odds											
Conditional probability											
Sampling											
Frequency distributions											
Histograms											
Mean, median, mode											
Std deviation											
Normal distribution											
Std normal & Z-scores											
Percentiles & quartiles											
Margin of error											

TOPICS COMPARISON MATRIX page 3 Math120 & Math 96 / MATH 120	MATH 96: solve rational equations	direct & inverse variation	solve proportions	rational functions	sq. rts.	cube rts	nth rts	rational exponents	operations with radicals	rationalize denominator	solve radical equations	radical functions	sq. root functions	nth root functions
Representing sets														
Empty set														
Equivalent sets														
Infinite vs finite sets														
Equal sets														
Subsets														
Venn diagrams														
Set operations														
Percents														
Taxes														
Simple interest														
Compound interest														
Geometry: Points and lines														
Geometry: Planes and angles														
Similar triangles			X											
Pythagorean Theorem														
Tessalations														
Perimeter, circumference, & area														
Volume														
Surface area														
Rt triangle Trig														
Fundamental counting principle														
Permutations & combinations														
Theoretical & empirical probability														
Probability of mutually exclusive events														
Odds														
Conditional probability														
Sampling														
Frequency distributions														
Histograms														
Mean, median, mode														
Std deviation														
Normal distribution														
Std normal & Z-scores														
Percentiles & quartiles														
Margin of error														

Appendix F: Math 95 Exit Skills versus Math 96 Prerequisites Matrix

SKILLS PREREQUISITES MATRIX Math 95 Skills vs Math 96 Prereqs	MATH 96 Prerequisite Skills																								
MATH 95 Exit Skills	number line	integers	numerical operations	primes	variables	variable operations	inequality symbols	absolute value	restricted value	coordinate plane	lines	polynomial operations	problem solving	exponents	factors	numerical long division	distributive property	numerical factoring	perfect squares	triangles	rational numbers	rational operations	rational expressions	roots	sqr & cubes	expression evaluation
subtract integers		X																								
use alt, symbols to indicate multiplication			X																							
multiply integers		X	X																							
divide integers		X	X																							
calculate the average of a set of real numbers			X																							
recognize and combine like terms					X	X																				
simplify alg. expressions containing variables					X	X																				
eval. Alg. expressions w/given variable values						X																				X
write equivalent fraction w/specified denom.																						X				
change fractions to decimals																						X				
change decimals to fractions																						X				
translate algebra to English													X													
translate English to algebra													X													
define equation, solution, and linear equa.																										
solve lin. equa w/Addition Principle of Equality																										
solve lin. equa w/Multiplication Prin. of Equal.																										
write & use Polya's steps for problem solving													X													
solve multiple step linear equations																										
define interval of real numbers	X																									
recog interval types (open, closed, half-open)																										
solve linear inequalities and graph solution																										
solve formulas for one variable																										
use formulas to solve applications																										
solve problems involving number phrases			X																							
solve consecutive numbers problems			X										X													
solve problems about odd or even numbers			X										X													
calculate percents of numbers			X																							
calculate fractional parts of numbers																						X				
solve decimals, fractions, and percent apps																						X				
define perimimeter, area, circumference																										
define radius, diameter, volume																										
i.d. & use geom. formulas to solve problems													X													
identify points on coordinate plane										X																

SKILLS PREREQUISITES MATRIX Math 95 Skills vs Math 96 Prereqs	MATH 96 Prerequisite Skills																									
MATH 95 Exit Skills	num-ber line	in-te-gers	nu-mer-ical op-era-tions	primes	var-ia-bles	vari-able op-era-tions	ine-qual-ity sym-bols	ab-so-lute val-ue	re-stric-ted val-ue	co-ordi-nate plane	lines	poly-no-mial op-era-tions	prob-lem sol-ving	ex-po-nents	factors	nu-mer-ical long divi-sion	dis-trib-utive prop-erty	nu-mer-ical fac-tor-ing	per-fect squares	tri-an-gles	ra-tion-al num-bers	ra-tion-al op-era-tions	ra-tion-al ex-pres-sions	roots	sqr & cubes	ex-pres-sion eval-ua-tion
define exponent, base, and power														X												
evaluate expressions with exponents														X												X
eval. numerical express; use order of oper.			X			X																				X
use variables in expressions						X																				X
define prime and composite numbers				X																						
i.d. numbers to be prime or composite				X																						
write prime factorization of composite nos.				X											X											
determine LCM of a set of natural numbers																										
use tests for divisibility by 2, 3, 5, 6, 9, and 10																										
define numerator, denominator, and recip.																					X					
write equivalent fraction in higher terms																					X	X				
reduce fraction to lowest terms																					X					
identify proper and improper fractions																					X					
multiply fractions																						X				
define reciprocal of a fraction																					X					
divide fractions																						X				
determine LCD of a set of fractions																						X				
add fractions																						X				
subtract fractions																						X				
read and write decimals																										
use operations with decimals																										
round decimals																										
define percent and explain use of symbol (%)																										
change decimals to percents																										
change fractions to percents																										
identfy natural nos.through real nos.																										
plot numbers on number line	X																									
define variable					X																					
define and use inequality symbols							X																			
define and determine absolute values								X																		
add integers		X																								
determine if integers are solutions		X											X													
define additive inverse			X																							

SKILLS PREREQUISITES MATRIX Math 95 Skills vs Math 96 Prereqs	MATH 96 Prerequisite Skills																								
MATH 95 Exit Skills	number line	integers	numerical operations	primes	variables	variable operations	inequality symbols	absolute value	restricted value	coordinate plane	lines	polynomial operations	problem solving	exponents	factors	numerical long division	distributive property	numerical factoring	perfect squares	triangles	rational numbers	rational operations	rational expressions	roots	sqr & cubes	expression evaluation
graph points on coordinate plane										X																
solve linear equations in two variables																										
identify points on graph of a line										X	X															
create ordered pair tables for given lin. equation										X																
define standard form of linear equation											X															
plot points and draw graph of given line										X	X															
determine x-intercept & y-intercept of given line										X	X															
recognize equations of vertical & horizontal lines											X															
calculate slope using two points on a line											X															
use slope & y-intercept to write equation of line											X															
define and identify parallel lines											X															
identify positive & negative slopes from graphs										X	X															
identify slopes of horizontal and vertical lines											X															
use slope and one point to graph line										X	X															
use slope & one pt to write equation of a line											X															
use two points to write equation of a line											X															
determine slope parallel to line w/known slope											X															
determine slope of line perp. To known line											X															
test pts for solution to system of lin. equations																										X
graph system of linear equations											X															
consistent, inconsistent, or dependent syst.											X															
use graph to estimate solution of lin. system										X																
state the properties of exponents														X												
simplify expressions w/integer exponents														X												
state the power rule for exponents														X												
state power of a product rule for exponents														X												
state power of a quotient rule for exponents														X												
write decimal numbers in scientific notation														X												
operations using scientific notation																										
add and subtract polynomials												X														
simplify polynom.(removing grouping symbols)																	X									

Appendix G: Math 95 Exit Skills versus Math 120 Prerequisites Matrix

SKILLS PREREQUISITES MATRIX Math 95 Skills vs Math 120 Prereqs page 1	MATH 120 Prerequisite Skills																			
MATH 95 Exit Skills	operations with whole numbers	using variables	using natural numbers	operations with fractions	operations with decimals	evaluate algebraic expressions	using exponents	operations with rational expressions	squaring numbers	using square roots	inequalities	using formulas	percent	ratios	proportions	order of operations	tables	graphs	division with numbers	subtraction with numbers
define exponent, base, and power							X		X											
evaluate expressions with exponents							X													
eval. numerical expressions using order of oper.	X															X			X	X
use variables in expressions		X																		
define prime and composite numbers																				
determine numbers to be prime or composite																				
write prime factorization of composite numbers																				
determine LCM of a set of natural numbers																				
use tests for divisibility by 2, 3, 5, 6, 9, and 10																			X	
define numerator, denominator, and reciprocal				X																
write equivalent fraction in higher terms				X																
reduce fraction to lowest terms				X																
identify proper and improper fractions				X																
multiply fractions				X																
define reciprocal of a fraction				X																
divide fractions				X																
determine LCD of a set of fractions				X																
add fractions				X																
subtract fractions				X																X
read and write decimals					X															
use operations with decimals					X															
round decimals					X															
define percent and explain use of symbol (%)													X	X	X					
change decimals to percents													X							
change fractions to percents													X		X					
identfy natural nos.through real nos.			X																	
plot numbers on number line			X																	
define variable		X																		
define and use inequality symbols																				
define and determine absolute values																				
add integers																				
determine if integers are solutions																				
define additive inverse																				

SKILLS PREREQUISITES MATRIX Math 95 Skills vs Math 120 Prereqs page 2	MATH 120 Prerequisite Skills																			
MATH 95 Exit Skills	operations with whole numbers	using variables	using natural numbers	operations with fractions	operations with decimals	evaluate algebraic expressions	using exponents	operations with rational expressions	squaring numbers	using square roots	inequalities	using formulas	percent	ratios	proportions	order of operations	tables	graphs	division with numbers	subtraction with numbers
subtract integers																				
use alt. symbols to indicate multiplication																				
multiply integers																				
divide integers																			X	
calculate the average of a set of real numbers																			X	
recognize and combine like terms		X																		
simplify alg. expressions containing variables		X				X														
eval. Alg. expressions w/given variable values						X														
write equivalent fraction w/specified denom.				X																
change fractions to decimals				X																
change decimals to fractions				X																
translate algebra to English																				
translate English to algebra																				
define equation, solution, and linear equation																				
solve lin. equa w/Addition Principle of Equality																				
solve lin. equa w/Multiplication Prin. of Equal.																				
write & use the Polya's steps for problem solving																				
solve multiple step linear equations																				
define interval of real numbers																				
recog. types of intervals (open, closed, half-open)																				
solve linear inequalities and graph solution											X									
solve formulas for one variable in terms of others												X								
use formulas to solve applications																				
solve problems involving number phrases																				
solve consecutive numbers problems																				
solve problems about odd or even numbers																				
calculate percents of numbers													X							
calculate fractional parts of numbers				X																
solve decimals, fractions, and percent apps				X	X								X							
define perimimeter, area, circumference																				
define radius, diameter, volume																				
identify & use geom. formulas to solve problems												X								
identify points on coordinate plane																				
graph points on coordinate plane																				

SKILLS
PREREQUISITES MATRIX

Math 95 Skills vs Math 120 Prereqs
page 3

MATH 95 Exit Skills	MATH 120 Prerequisite Skills																			
	operations with whole numbers	using variables	using natural numbers	operations with fractions	operations with decimals	evaluate algebraic expressions	using exponents	operations with rational expressions	squaring numbers	using square roots	inequalities	using formulas	percent	ratios	proportions	order of operations	tables	graphs	division with numbers	subtraction with numbers
solve linear equations in two variables																				
identify points on graph of a line																				
create ordered pair tables for given lin. equation																	X			
define standard form of linear equation																				
plot points and draw graph of given line																				
determine x-intercept & y-intercept of given line																				
recognize equations of vertical & horizontal lines																				
calculate slope using two points on a line																				
use slope & y-intercept to write equation of line																				
define and identify parallel lines																				
identify positive & negative slopes from graphs																				
identify slopes of horizontal and vertical lines																				
use slope and one point to graph line																				
use slope & one pt to write equation of a line																				
use two points to write equation of a line																				
determine slope parallel to line w/known slope																				
determine slope of line perp. To known line																				
test pts for solution to system of lin. equations																				
graph system of linear equations																				
consistent, inconsistent, or dependent syst.																				
use graph to estimate solution of lin. system																				
state the properties of exponents							X													
simplify expressions w/integer exponents							X		X											
state the power rule for exponents							X													
state power of a product rule for exponents							X													
state power of a quotient rule for exponents							X													
write decimal numbers in scientific notation																				
operations using scientific notation																				
add and subtract polynomials																				
simplify polynom.(removing grouping symbols)																				

Appendix H: Math 96 Exit Skills versus Math 120 Prerequisites

SKILLS PREREQUISITES MATRIX Math 96 Skills vs Math 120 Prereqs page 1	MATH 120 Prerequisite Skills																			
MATH 96 Exit Skills	operations with whole numbers	using variables	using natural numbers	operations with fractions	operations with decimals	evaluate algebraic expressions	using exponents	operations with rational expressions	squaring numbers	using square roots	inequalities	using formulas	percent	ratios	proportions	order of operations	tables	graphs	division with numbers	subtraction with numbers
define & evaluate absolute value		x																		
operations with real numbers			x																x	x
define order of operations	x																			
use order of operations to evaluate expressions	x	x	x			x	x									x			x	x
combine like terms		x																		
solve one variable linear equations		x																		
solve absolute value equations																				
use formulas in applications		x										x								
solve for variable in multivariable equation		x																		
use interval notation											x									
solve linear inequalities & graph on no. line											x									
solve compound inequalities & graph on no. line											x									
solve absolute value inequalities											x									
define relation, domain, range, & function																				
use function notation																				
use vertical line test																				
define linear function																				
determine domain of non-linear function																				
evaluate funtions																				
graph linear inequality in coordinate plane																				
define consistent, inconsistent, dependent systems																				
solve sytems of two linear equations																				
solve applications using systems of linear equations																				
solve sytems of two linear inequalities																				
use exponent rules to simplify expressions							x		x											
define monomial, degree, coefficient, polynomial																				
add & subtract polynomials																				
multiply polynomials																				
divide by momomial																				
divide polynomials using long division																				
factor out GCF of polynomial																				
factor 4-term polynomials by grouping																				

SKILLS PREREQUISITES MATRIX

Math 96 Skills vs Math 120 Prereqs

page 2

	MATH 120 Prerequisite Skills																			
MATH 96 Exit Skills	operations with whole numbers	using variables	using natural numbers	operations with fractions	operations with decimals	evaluate algebraic expressions	using exponents	operations with rational expressions	squaring numbers	using square roots	inequalities	using formulas	percent	ratios	proportions	order of operations	tables	stat graphs	division with numbers	subtraction with numbers
factor quadratics																				
solve quadratic equations																				
use factor th. to create equation from given roots												X								
state Pythagorean Theorem												X								
use Pythagorean Theorem to solve apps																				
define rational expression								X												
list restrictions for variables in rational expression								X												
simplify rational expressions								X												
multiply and divide rational expressions				X				X												
add and subtract rational expressions				X				X												
define ratio & proportion														X	X					
solve rational equations				X				X												
solve direct variation applications												X								
solve inverse variation problems												X								
solve combined variation problems												X								
define radical sign, radicand, radical expression																				
define square root & cube root																				
evaluate radical expressons																				
simplify square roots & cube roots																				
define rational exponents																				
simplify & evaluate rational exponent expressions																				
use operations with radical expressions										X										
rationalize denominators with radicals																				
solve radical equations										X										
identify domain of radical functions																				
state the quadratic formula												X								
solve quadratic equations												X								

Appendix J: Instructor Interviews Instruments

Math 95 Instructor Interview Name: ______________________________

(Please sign Consent Form) Date: _______________

1. What is your status at UNLV? (GA?, PTI?):
2. How long have you been teaching Math 95?
3. Do you often need to cover supplemental topics (like basic arithmetic) to prepare students for the Math 95 content?
4. About what % of students enter your class in need of supplemental material? (i.e., What % is not fully prepared for success in Math 95?):
5. What particular topics or skills fall into this supplemental instruction category? (i.e., Where are the weaknesses?):
6. Do you think these weaknesses contribute to students' failure of Math 95?
7. In general, do you feel that the content of Math 95 would help more students if it covered even lower-level material than it does?
8. If you could change the content, what would be your top choice(s) for additional content?

Math 96 Instructor Interview Name: ____________________

(Please sign Consent Form) Date: ____________

1. What is your status at UNLV? (GA?, PTI?):
2. How long have you been teaching Math 96?
3. Do you often need to cover supplemental topics (like solving equations) to prepare students for the Math 96 content?
4. About what % of students enter your class in need of supplemental material? (i.e., What % is not fully prepared for success in Math 96?):
5. What particular topics or skills fall into this supplemental instruction category? (i.e., Where are the weaknesses?):
6. Do you think these weaknesses contribute to students' failure of Math 96?
7. In general, do you feel that the content of Math 96 would help more students if it covered even lower-level material than it does?
8. If you could change the content, what would be your top choice(s) for additional content?

Math 120 Instructor Interview Name: ___________________________________

Date: ___________

(Request signature on Consent Form)

1. What is your status at UNLV? (GA?, PTI?):
2. How long have you been teaching Math 120?
3. Do the sections of the Blitzer book that you cover agree with the website information?
4. So there's no actual Algebra covered?
5. Do you often need to cover supplemental topics (like solving equations) to prepare students for the 120 content?
6. About what % of students enter your class in need of supplemental material? (i.e., What % is not fully prepared for success in 120?):
7. What particular topics or skills fall into this supplemental instruction category? (i.e., Where are the weaknesses?):
8. Do you think these weaknesses contribute to students' failure of Math 120?
9. On what skills or topics in particular do you think prerequisite preparation for Math 120 should focus?

Appendix K: Survey for Math 120 Instructors

Q1 What is your status at UNLV?

- ❍ Full-time Faculty
- ❍ Part Time Instructor
- ❍ Graduate Assistant
- ❍ Other

Q2 How long have you been teaching Math 120?

Q3 Which textbook are you currently using?

Q4 Do you often need to cover supplemental material to prepare students for the Math 120 content? If so, what material?

Q5 About what percentage of your students require the supplemental assistance?

Q6 In general, what mathematical deficiencies have you observed in your students that inhibit their success in your Math 120 class? (That is - what do they not know, but should know coming into this class?)

Q7 Many of your students may have taken Math 95 and/or Math 96 as prerequisite(s). On what particular skills or topics do you feel prerequisite courses should focus as preparation for Math 120?

Q8 What topics or skills presented in Math 120 are the most challenging for your students?

Q9 If you had to choose just one topic or skill that you feel is the most important for success in Math 120, what would it be?

Q10 Please enter any comments that you feel are important regarding information that could lead to improvements in student success.

Appendix L: Survey for Programs

Math 120 Satisfaction/Development

Q37 Thank you in advance for your time. The following questions will help us identify your role at the university, and your student's required math course.

Q1 I am a

- ❍ Faculty member (1)
- ❍ Part time instructor (2)
- ❍ Graduate teaching assistant (3)
- ❍ Advisor (4)

Q5 I work in the following college(s):

Q4 I work in the following department(s). If multiple departments, list individually or type "all" as appropriate:

Q7 In order to graduate, students in my area are generally required to take (assume they do not need to enroll in a prerequisite class, and though multiple classes may be allowed, enter the minimum course required)

- ❍ MATH 120 (Fundamentals of College Math) (1)
- ❍ MATH 124 (College Algebra) (2)
- ❍ MATH 126 (Precalculus) (3)
- ❍ MATH 181 (Calculus) or higher (4)

Display This Question:
If Our students are typically required to take MATH 124 (College Algebra) Is Selected

Q8 Even though in my area we currently require MATH 124, it may be possible that a revised MATH 120 course could satisfy the math requirement for our majors

- ❍ Yes (1)
- ❍ No (2)

Display This Question:
If Our students are typically required to take MATH 126 (Precalculus) Is Selected
Or Our students are typically required to take MATH 181 (Calculus) or higher Is Selected
Or Even though in my area we currently require MATH 124, it may be possible that a revised MATH 120 course could satisfy the math requirement for our majors No Is Selected

Q37 Even though MATH 120 is NOT a class considered for our majors, I would still like to continue the survey

- ❍ Yes (1)
- ❍ No (2)

Condition: No Is Selected. Skip To: End of Survey.

Q38 The following questions will help us understand the positive and negative aspects of the MATH 120 course as it exists today.

Q17 Generally speaking, how satisfied are you with the experience your students have had in the course

- ❍ Extremely satisfied (1)
- ❍ Somewhat satisfied (2)
- ❍ Neither satisfied nor dissatisfied (3)
- ❍ Somewhat dissatisfied (4)
- ❍ Extremely dissatisfied (5)

Display This Question:
If Generally speaking, how satisfied are your students with the experience they have had in the course? Neither satisfied nor dissatisfied Is Not Selected

Q18 Briefly describe at least one strength or weakness to support your level of satisfaction:

Q43 Have students in any way communicated their satisfaction with the course to you?

- ❍ Yes (1)
- ❍ No (2)

Display This Question:

If Have students in any way communicated their satisfaction with the course? Yes Is Selected

Q19 Generally speaking, how satisfied are your students with the experience they have had in the course?

- Extremely satisfied (12)
- Somewhat satisfied (13)
- Neither satisfied nor dissatisfied (14)
- Somewhat dissatisfied (15)
- Extremely dissatisfied (16)

Display This Question:

If Have students in any way communicated their satisfaction with the course to you? Yes Is Selected

Q46 Briefly describe how this information was conveyed to you:

Display This Question:

If Generally speaking, how satisfied are your students with the experience they have had in the course? Neither satisfied nor dissatisfied Is Not Selected

Q20 Briefly describe what you have found students identify to be the strengths or weaknesses in the course:

Q45 I am familiar with the current format of the class (i.e. the manner in which content is presented)

- Yes (1)
- No (2)

Display This Question:

If I am familiar with the current format of the class (i.e. the manner in which content is presented) Yes Is Selected

Q43 For our students, the content is generally presented in a manner that is appropriate for an introductory course

- Strongly agree (1)
- Somewhat agree (2)
- Neither agree nor disagree (3)
- Somewhat disagree (4)
- Strongly disagree (5)

Display This Question:

If For our students, the content is generally presented in a manner that is appropriate for an intro... Neither agree nor disagree Is Not Selected

Q44 Briefly describe at least one strength or weakness to support your level of satisfaction:

Q12 I am familiar with the content presented in MATH 120 as it exists today

- Yes (1)
- No (2)

Display This Question:

If I am familiar with the content presented in MATH 120 as it exists today Yes Is Selected

Q13 For our students, the content is generally presented at a difficulty level that is appropriate for an introductory course

- ❍ Yes (1)
- ❍ No, it is too high (2)
- ❍ No, it is too low (3)
- ❍ Don't know / No opinion (4)

Display This Question:

If I am familiar with the content presented in MATH 120 as it exists today Yes Is Selected

Q14 Briefly describe what you consider to be strengths and/or weaknesses in course content:

Q16 The following broad topics are currently presented in the course, check all that seem pertinent to your students (there is an opportunity later to specify what you may want to add)

- ❑ Set theory (1)
- ❑ Consumer math/financial management (2)
- ❑ Geometry (3)
- ❑ Statistics (4)
- ❑ Counting methods/probability theory (5)

Q41 I have noticed students are generally prepared (mathematically) when enrolled in subsequent courses

- ❍ Strongly agree (1)
- ❍ Somewhat agree (2)
- ❍ Neither agree nor disagree (3)
- ❍ Somewhat disagree (4)
- ❍ Strongly disagree (5)
- ❍ Don't know / No opinion (6)

Display This Question:

If I have noticed students are generally prepared (mathematically) when enrolled in subsequent courses Somewhat disagree Is Selected

And I have noticed students are generally prepared (mathematically) when enrolled in subsequent courses Strongly disagree Is Selected

Q42 Please list at least two topical examples to support your conclusion on mathematical readiness

Q39 The following questions will help guide us towards a more meaningful course for our students.

Q41 The structure of this course is important to me (enrollment, number of days per week, instructor, etc.)

- ❍ Yes (1)
- ❍ No (2)

Display This Question:

If The structure of this course is important to me (class times, instructor, etc.) Yes Is Selected

Q25 The course should have students with similar (or the same) major field of study

- Yes (1)
- Maybe (2)
- No (3)
- No opinion (4)

Display This Question:

If The structure of this course is important to me (class times, instructor, etc.) Yes Is Selected

Q39 It is important who teaches this course (yes/no). If yes, please clarify:

Display This Question:

If The structure of this course is important to me (number of days per week, instructor, etc.) Yes Is Selected

Q40 It is important how many days per week this class meets, and for how long (yes/no). If yes, please clarify:

Display This Question:
If The structure of this course is important to me (number of days per week, instructor, etc.) Yes Is Selected

Q42 I would suggest this class have a maximum enrollment of

- 30 students (1)
- 45 students (2)
- 60 students (3)
- 90 students (4)
- No opinion (5)

Display This Question:
If I would suggest this class have a maximum enrollment of 60 students Is Selected
Or I would suggest this class have a maximum enrollment of 90 students Is Selected

Q43 With enrollment of this size, a breakout (a.k.a. discussion or recitation) is an essential component for student success

- Strongly agree (1)
- Somewhat agree (2)
- Neither agree nor disagree (3)
- Somewhat disagree (4)
- Strongly disagree (5)

Q23 The pedagogical practices used in the course are important to me

- Yes (1)
- No (2)

Display This Question:
    If The pedagogical practices used in the course are important to me Yes Is Selected

Q26 What portion of the class should be devoted to writing?

- Significant (more than half the time) (1)
- Partial (between a quarter and half of the time) (2)
- Subsidiary (less than a quarter of the time) (3)
- No opinion (4)

Display This Question:
    If The pedagogical practices used in the course are important to me Yes Is Selected

Q38 It would be beneficial for students to be lectured via videos outside of class, and in class only be actively engaged in learning activities

- Yes (1)
- Maybe (2)
- No (3)
- No opinion (4)

Display This Question:
    If The pedagogical practices used in the course are important to me Yes Is Selected

Q44 It is important for MATH 120 students to see math as a "tool" used to answer a bigger question. In other words, the mathematics should be embedded in other real world problems

- Strongly agree (1)
- Somewhat agree (2)
- Neither agree nor disagree (3)
- Somewhat disagree (4)
- Strongly disagree (5)

Display This Question:

If The pedagogical practices used in the course are important to me Yes Is Selected

Q46 It is more important for students to have problem solving skills as compared to being able to memorize or use specific math facts or formulas

- Strongly agree (1)
- Somewhat agree (2)
- Neither agree nor disagree (3)
- Somewhat disagree (4)
- Strongly disagree (5)

Q22 The specific content of the revised course is important to me

- Yes (1)
- No (2)

Display This Question:
If The specific content of the course is important to me Yes Is Selected

Q24 Of the following topics, identify the relevance you believe they would have for your students

	Very (1)	Somewhat (2)	Not at All (3)	I Don't Know (4)
Percents and Ratios (1)	❍	❍	❍	❍
Financial calculations (2)	❍	❍	❍	❍
Set theory and Venn diagrams (3)	❍	❍	❍	❍
Formula manipulation (when and how to use formulas) (4)	❍	❍	❍	❍
Displaying and interpreting information graphically (5)	❍	❍	❍	❍

Voting and apportionment (10)	❍	❍	❍	❍
Points, lines, planes and angles (6)	❍	❍	❍	❍
Polygons and circles (7)	❍	❍	❍	❍
Area, perimeter, etc. (8)	❍	❍	❍	❍
Right triangle trigonometry (9)	❍	❍	❍	❍
Sampling and frequency distributions (11)	❍	❍	❍	❍
Measures of central tendency (12)	❍	❍	❍	❍
Normal distributions (13)	❍	❍	❍	❍

Risk ratios (14)	❍	❍	❍	❍
Validity and reliability (15)	❍	❍	❍	❍
Mutually exclusive events and odds (16)	❍	❍	❍	❍
Fundamental counting principle (17)	❍	❍	❍	❍
Permutations and combinations (18)	❍	❍	❍	❍
Truth tables (19)	❍	❍	❍	❍
Conditional statements (20)	❍	❍	❍	❍
Inductive and deductive reasoning (21)	❍	❍	❍	❍

Display This Question:

If The specific content of the revised course is important to me Yes Is Selected

Q45 List any additional topics not already listed that should be included:

Q40 Thank you. Please let us know if you are willing to assist us in further development of the course.

Q34 I am interested in serving to assist in the development of this course

- ❍ Yes (1)
- ❍ No (2)

Display This Question:

If I () interested in serving to assist in the development of this course am Is Selected

Q35 Enter your name

Display This Question:

If I () interested in serving to assist in the development of this course am Is Selected

Q36 Enter your email address

Appendix M: Coding of Programs Survey

Open Codes	Axial Codes	Selective Codes
students feel course unecessary for their major	alignment to major	
do not see connection to their major	alignment to major	
seems to not fulfill the needs of students	alignment to major	
strength: course has even balance	balanced*	
strength: students can use calculator	calculator usage*	
lack of consistency between instructors	consistency	
students complain that they do not learn math	content	
content not helpful if student changes major	content	
students don't feel they have learned anything	content	
need to look up related information online	content	
algebra content will not help the course	content	
all students should take Math 124	content	
Math 120 is easier than Math 96	course comparison	
Math 120 is the easiest math course	course comparison	
no particular order to material	disjoint content	
material does not build on skills	disjoint content	
concepts can feel disjoint	disjoint content	
discussion sections do not coincide with lectures	disjoint content	
disconnect between material and applications	disjoint content	
department final is problem	disjoint final	
not prepared for departmental final	disjoint final	curriculum
students not prepared for departmental final	disjoint final	
departmental final	disjoint final	
objection to how final exam is constructed	disjoint final	
strength: basic math about finance is beneficial	finance math*	
strength: lab	format*	
strength: lots of practice	format*	
useful for non-tech majors	good for non-techs*	
issue is software	hw software	
homework software extremely unforgiving	hw software	
strength: free from algebra is OK	no algebra*	
no need for prerequisite for Math 120	objection to prereqs	
irrelevant prerequisite	objection to prereqs	
frustrated with on-your-own computer instruction	platform	
homework builds false sense of understanding	platform	
unclear course book	poor text	
course needs more practical mathematics	practical content	
strength: real world examples are great	real-world*	
strength: using real world math	real-world*	
strength: real-world applications	real-world*	
need to teach use of spreadsheet tool	tech content	

Open Codes	Axial Codes	Selective Codes
single biggest obstacle to graduation	barrier to progress	
do not do well on tests	challenges students	
too much material	challenges students	
need to repeat course is barrier to graduation	challenges students	
math courses have been a nightmare	challenges students	
not interested in their learning	character of student	
students have very little confidence	character of student	
math anxiety	character of student	
fear of math leads to frustration	math anxiety	
students seem prepared for ECON 261	prepared students*	
barrier towards degree	student challenges	
struggle with material	student challenges	
too much material	student challenges	
course moves very quickly	student challenges	
students not prepared	unprepared students	
1/3 do not know order of operations	unprepared students	
students enter with insufficient skills	unprepared students	
students can't do basic math	unprepared students	student preparation
cannot do 60% of 20 in their head	unprepared students	
don't understand basic stats(mean, median, mode)	unprepared students	
students are too calculator dependent	unprepared students	
don't know how to set up a problem	unprepared students	
students make ridiculous miscalculations	unprepared students	
students are unable to calculate a percentage	unprepared students	
students are unable to solve for a single variable	unprepared students	
students need step-by-step instructions	unprepared students	
material should have been learned in high school	unprepared students	
can't simplify without calculator	unprepared students	
cannot solve fractions	unprepared students	
my students are not able to do math	unprepared students	
hard time understanding ESL professors	ESL instructor	
language barrier between students and instructor	ESL instructor	
students cannot understand instructor	ESL instructor	
language barrier between students and instructor	ESL instructor	
instructors have difficulty communicating	ESL instructor	
difficulty understanding instructors	ESL instructor	instructor
instructor language barriers	ESL instructor	
cannot understand instructor's English	ESL instructor	
students struggle to understand instructors	ESL instructor	
language barrier between students and instructor	ESL instructor	
instructor strong accent not easy to understand	ESL instructor	
students cannot understand instructor accents	ESL instructor	
instructors have not been helpful	instructor attitude	
instructors do not seem to care about helping students	instructor attitude	
instructors not approachable	instructor attitude	

Open Codes	Axial Codes	Selective Codes
instructor not open to answering questions	instructor attitude	instructor
professors aren't willing to explain	instructor attitude	
dependent on strength of instructors	instructor is key	
professors have difficulty communicating content	level of instruction	
instructor's inability to explain	level of instruction	
lecture not best way	pedagogy	
issue is instruction	pedagogy	
execution of course needs to be revamped	pedagogy	
instructors great at math but poor at teaching	pedagogy	
poor instructors	pedagogy	
professors assume all students at same level	pedagogy	
students expected to be at certain knowledge level	pedagogy	
better math teachers needed	pedagogy	
instructors have no teaching skills	pedagogy	
needs revision to the way course is taught	pedagogy	
instructors very rigid and not supportive	pedagogy	
instructors need more training	pedagogy	
grading is too loose	pedagogy	
poor instructors	pedagogy	
poor teaching techniques	pedagogy	
very dry and boring	pedagogy	
need professor training	pedagogy	
students not engaged	pedagogy	
poor instruction	pedagogy	
instructors not teaching - just move thru content	pedagogy	
instructor not explaining in understandable way	pedagogy	
students do not learn best via lecture	pedagogy	
students need to be actively engaged	pedagogy	
professors need course on how to teach	pedagogy	
need to incorporate ways to get students engaged	pedagogy	
lack of understanding due to poor instruction	pedagogy	
cannot connect math skills to use beyond classroom	transfer of skills	
need connection between math and use outside class	transfer of skills	administration
problem with Math Department	Math Dept.	
not enough sections	scheduling	
amount of courses and scheduled times	scheduling	supplemental assistance
strength is tutoring center	added resources*	
strength is supplemental resources	added resources*	
strength: tutoring sessions	added resources*	
difficulty getting added support	lack of support	

*positive responses

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