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Gaps in Developmental Mathematics Course Sequence Impede Success in College Algebra

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GAPS IN DEVELOPMENTAL MATHEMATICS COURSE SEQUENCE IMPEDE SUCCESS IN COLLEGE ALGEBRA

A Dissertation

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Abstract

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Community colleges are undergoing a transformation. Historically, they have been focused on improving access to higher education; now the focus has shifted to student success. This transformation is evident in the concerted effort to improve student graduation rates and decrease the amount of time spent to complete degrees. For community colleges, the key to this success must include reform and improvement in developmental education. Within developmental education, mathematics presents the biggest challenge for the largest number of students. It was found that many students fail to maintain continuous enrollment in their developmental mathematics course sequence (Bailey, 2009; Bailey & Cho, 2010; Bailey, Jeong, & Cho, 2010). Accordingly, the purpose of this study was to investigate the impact of gaps or stop outs within the developmental mathematics course sequence on the successful completion of college algebra. The fall 2004 first-time-in-college cohort of students at a rural community college was selected for this study. Their record of enrollment in the developmental mathematics courses over a six-year period was collected. The enrollment data was

analyzed via a binary logistic regression. The results indicate that each gap within the developmental mathematics course sequence increases the risk of failure by 1.5 times.

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The current business climate characterized by increased competition and an abundant supply of workers is demanding a better-educated workforce and looking toward community colleges to deliver it. A 2005 ACT study on college readiness found in regards to the high school graduating class of 2004, they "aren't ready for college or the workplace . . . [and] given the demands of today's global economy, this situation is nothing short of a crisis" (p. i). The ACT (2005) study also found supporting evidence in the U.S. Department of Education's National Commission on the High School Senior Year (2001) "although the high school diploma is a prerequisite for college admission and most jobs, students who earn one have no guarantee that they are prepared for college level work or entry-level employment" (p.1). Individually, students also have found that a high school diploma will no longer provide them with necessary skills to earn a living. Zeidenberg (2008) found that earnings from a high school education alone are no longer sufficient to maintain a basic standard of living for a family. These driving forces for post-secondary education have fueled dramatic growth at community colleges. However, this growth has not translated into more graduates. Scott-Clayton (2011) found "out of 100 students entering a community college for the first time, only 15 will complete a degree or certificate within three years" (p. 1).

In Texas this statistic, along with the need for a better-educated workforce has begun to influence public policy decisions. For example, the Governor's educational priorities for 2010 declared that the state must:

> raise the overall quality of education in Texas by aligning the higher education standards more closely with the needs of business, balancing accountability with

> incentives for teacher and school performance and increasing the emphasis on core subject areas like mathematics, reading, and science. (Texas Governor's Office, 2010)

This position was in response to business's demand for a better-educated workforce and more graduates. This is not a new criterion from the business sector: they have made prior claims for a better prepared workforce.

Holter and Kopka (2001) indicated that "in the early 1990s, business, government, and educational leaders recognized deficiencies in the educational preparation of students" (p. 138). In 1999, Bottge also observed that the "National Research Council (NRC, 1989) warned that the mathematics skills of American children are woefully inadequate for the kinds of problem solving required in the workplace" (p. 81). Bruner (as cited in Bottge, 1999), also found that educators need to increase the ability of their students to generalize problems by incorporating strategies that ensure "students understand the underlying structure of the problem . . . and by stimulating in students a desire to learn" (p. 82). The problem solving aspect found in algebra represents a portion of the skill sets that businesses seek in college graduates. Bottge stated, "all students . . . need to be mathematically proficient to a level that will allow them to 'figure out' math-related problems they encounter in the community and in future work situations" (p. 81). For example, take the metaphor of learning to ride a bicycle. Once a person has mastered the skill of riding a bicycle, the rider is able to pick up a bicycle after an extended hiatus and ride it with proficiency, adapting to an ever-changing environment. The same can be said about algebraic problem-solving skills, graduates need to master problem-solving skills in college to be able to apply those techniques to the dynamic environments in the

workplace. As Adelman (2006) emphasized in his revisit to the *Toolbox* that "the world has gone quantitative: business, geography, criminal justice, history, allied health fields – a full range of disciplines and job tasks tells students why math requirements are not just some abstract school exercise" (p. xix).

Despite business's repeated calls for a better-prepared student from colleges, post-secondary institutions still fall short of providing the necessary skills demanded by the employers. This was evident in Secretary of Education Spelling's conclusion that "graduates today are lacking important skills such as reading, writing, problem solving, and critical thinking" (Yordy, 2008, p. 51). These repeated shortcomings from post-secondary institutions have finally sparked a more aggressive response from policy makers in Texas. One clear example was evident in the governor's priorities for education, which have initiated the process to implement policies that will help align the educational institutions' student outcomes with the demands of business.

This change in philosophy was evident in the Texas Higher Education Coordinating Board 2008 funding study, which recommends that a greater emphasis be placed on student success, and resources be aligned to support these goals. As a result, the Coordinating Board recommended three fundamental changes to the funding model for community colleges that would align the state's allocation of resources to focus on student success:

- Base funding on outcomes rather than on inputs. Currently, funding is based on attempted semester credit hours or contact hours (inputs). This recommendation bases funding on completed semester credit hours or contact hours (outcomes).

- Provide funding at levels that not only allow institutions to continue meeting participation goals, but enable them to put the infrastructure, policies, and programs in place necessary to retain students more effectively and improve student performance.
- Provide institutional performance funding to recognize achievement in meeting student success goals, such as increasing the number of degrees and certificates awarded as well as increasing the number of transfers from two-year institutions to universities. (p. 3)

However, in spite of the alignment provided by the Coordinating Board's recommendation, the state legislature failed to fund it. This lack of funding has become a common occurrence and exacerbates an already difficult situation for community colleges. In another study, the Texas Legislative Budget Board (2009) found that community colleges provide a significant portion of higher education in Texas: "sixty-one percent of lower division academic semester credit hours occurred at two-year institutions" (p. 443). The two statewide perspectives from the Coordinating Board and Budget Board provide evidence that community colleges are facing a transition from the traditional focus on providing access to education to an emphasis on student success outcomes to a larger population. This increased focus on producing more graduates and penalties for not doing so has community colleges scrambling to identify the bottlenecks.

The shift toward a success-centered approach has had an especially significant impact on community colleges due to their large concentration of academically unprepared students. Most community colleges, by design, are open-admission institutions. Zeidenberg (2008) found that open-admission policies, in effect, concentrate

many of the students that have been unprepared for the rigors of college. Zeidenberg's study revealed, "42% of first-year students at two-year public schools enrolled in at least one remedial course, compared to 20% at public four-year schools and 12% at private four-year schools" (p. 53). These percentages reveal the large number of academically unprepared students at community colleges. In order for these students to progress to college-level courses, they must first complete their developmental education course sequences.

Bailey, Jeong, and Cho (2008), defined developmental education as a mechanism "designed to provide students who enter college with weak academic skills the opportunity to strengthen those skills enough to prepare them for college level coursework" (p. 1). Community colleges have historically provided developmental education; however, today the number of students in need of remediation has increased dramatically to the point that "developmental education is one of the most difficult issues facing community colleges today" (Bailey, 2009, p. 1). This problem is a result of several factors: the open admission policies concentrate many of the at-risk students on community college campuses, and there is a high volume of students arriving without the requisite skills for college level courses. Another significant factor with developmental education is that only one-third of the students complete the course sequence and ultimately transition to college level courses (Bailey, Jeong, & Cho (2008).

Background Information

This study was conducted at a rural community college in Texas, here in after referred as the Community College. According to the 2003-2004 Community College Fact Book, the college enrolled approximately 5,140 students, 4,015 full-time

equivalents, of which 80% were Hispanic and 62% were women. The average age of the student body was 25 years old, and 56% of the students were enrolled part-time. In the fall 2004 semester, the Community College enrolled 885 first-time-in-college students; of these students, 71% required developmental mathematics. Of the students placed in developmental mathematics, approximately 26% successfully completed college algebra after six years. These statistics at the study site are consistent with Bailey and Cho's (2010) findings that "about 60 percent of incoming students are referred to at least one developmental course" (p. 1).

The Community College utilized various assessment instruments to determine college readiness, as well as proper placement in the developmental course sequence. According to Bailey, Jeong, and Cho (2010), sequences are defined as a

> process that begins with initial assessment and referral to remediation and ends with completion of the highest-level developmental course. . . . At times we [researchers] extend the notion of 'sequence' into the first-level college course in relevant subject area – known as the 'gatekeeper' course. (p. 1)

The developmental mathematics course sequence at the Community College consists of three courses. The first course is basic mathematics, followed by elementary algebra, and then intermediate algebra. At the conclusion of the developmental mathematics course sequence, the students are deemed to be college ready and should proceed to enroll in the college algebra the "gate-way" course.

The process began with an assessment of the student's skills. At the study site, this was accomplished utilizing standardized assessment instruments such as that of the ACT, the College Board's ACCUPLACER, the College Board's Scholastic Aptitude Test

(SAT), the Texas Academic Skills Program (TASP), or the Texas Assessment of Academic Skills (TAAS), a high school exit assessment. Students were then placed into appropriate levels of remediation according to their assessment scores or were classified as college ready and moved directly to college-level courses. Table 1 illustrates the various minimum assessment scores used at the study site to determine college readiness in mathematics.

Table 1

College Readiness Benchmarks at the Community College

Assessment tool	Minimum college readiness scores for mathematics
ACT	Composite 23 with 19 in Mathematics
SAT	Combined 1070 with 500 in Mathematics
TAAS	86 Mathematics
ACCCUPLACER	81 Mathematics
TASP	230 Mathematics

Note. Adapted from The Community College Catalog, 2003-2005, pp. 40-45.

For those students who do not meet the minimum requirements for college algebra, a further assessment of their score determines the proper placement within the developmental course sequence. At the study site, according to the 2003-2005 catalogue, students who are deficient in multiple areas are required by state law to be enrolled in at least one developmental program. For example, if a student is placed in both developmental English and mathematics, the student could satisfy the regulation by enrolling in either English or mathematics. Students self-select which developmental course in which to enroll; however, if students require developmental courses in several

areas, they often delay the mathematics course sequence or postpone the next successive course in the sequence producing time gaps in their progress toward college algebra. Table 2 below, illustrates the various assessments instruments and their respective scores utilized to place students at the appropriate level.

Table 2

Developmental Mathematics Placement Scores

Course	Accuplacer	TASP	ASSET	Compass
Basic mathematics	0-29	0-189	0-20	0-20
Elementary algebra	30-62	190-215	21-31	21-31
Intermediate algebra	63-80	216-229	32-37	32-38
College algebra	81-100	230+	38+	39+

Note. Adapted from The Community College Registration Guidelines, 2004-2005. American College of Testing (Acculacer, Asset, & Compass), Texas Higher Education Assessment (TASP)

Statement of the Problem

Since community colleges are open-admission institutions, they face the challenge of educating a large number of at-risk students who arrive at their institutions unprepared for college-level courses. In order for community colleges to make significant improvements in student success, they must improve the completion rate for the course sequence by addressing the progression of students through the course sequence.

At the study site, developmental students who placed into the lowest level of the mathematics course sequence spend a minimum of three semesters in developmental mathematics courses before they are eligible to enroll in college algebra. Students often

perceive developmental courses as an obstacle. However, a better representation is to view these obstacles as milestones for the student: "*milestones* are measurable educational achievements that include both conventional terminal completions, such as earning a credential or transferring to a baccalaureate program, and intermediate outcomes, such as completing developmental education or adult basic skills requirements" (Leinbach & Jenkins, 2008, p. 1). Thus, each course completion is a milestone moving the student closer to the next goal of passing college algebra. The successful completion of college algebra is perhaps the biggest milestone for most students. The 2005 ACT College Readiness cited Adelman (1999) who found:

> of all pre-college curricula, the highest level of mathematics one studies in secondary school has the strongest continuing influence on bachelor's degree completion. Finishing a course beyond Algebra 2 . . . more than doubles the odds that a student who enters postsecondary education will complete a bachelor's degree. (p. 21)

Leinbach and Jenkins (2008) similarly found that "for college-level, workforce, and transfer students, practically all of the gatekeeper course completions and credit thresholds are positive and significant for any milestone achievement. Passing the basic gatekeeper course in math and English are very strongly correlated with postsecondary achievements" (p. 20).

However, at each level, students drop out of the developmental mathematics course sequence, and never pass college algebra. Since success in college algebra was proven to be a predictor of future college success (Adelman, 1999; Leinbach & Jenkins, 2008), it is

valuable to attempt solutions that improve developmental mathematic completions in order to increase current graduation rates. Bailey et al. (2008) found that

> completing a full developmental sequence does allow students with very weak skills to catch up to those with stronger skills—students referred to courses three or more levels below college-level do as well in their first college course as those who tested into the highest level of remediation. (p. 16)

At the study site, many students fail to complete the developmental mathematics course sequence or postpone college algebra until their last semester before graduation. This practice was also documented by Bailey et al. (2008), who found that:

> 1) only a minority of students who need developmental education complete their full sequence of developmental courses; 2) many never pass their first developmental course in their sequence, and 3) a majority of those students who do not complete their full sequence of courses fail to do so because they do not enroll in their initial course or a subsequent course, not because they fail or drop out of any of the courses they attempt. (p. 22)

Preliminary examination of students' progress through the developmental mathematics revealed numerous semester gaps in the course sequence. These gaps may represent a factor impeding success in college algebra.

Gaps within the developmental course sequence can jeopardize the successful completion of college algebra and negate Thorndike's principles of the Law of Exercise, "use it or lose it." He proposed that, "other things being equal, exercise strengthens the bond between situation and response" (Bigge & Shermis, 1992, p. 48). This learning theory goes back to "Aristotle's laws of association . . . the law of frequency, which states

that the strength of an association depends on the frequency with which it occurs" (Hergenhahn & Olson, 2005, p. 213). Nairne (2002) elaborated on the process from which a person stores and recalls short-term and long-term memory. He stated that "permanent knowledge is activated, as a result of on-line cognitive processing. . . . Activation is assumed to decay spontaneously with the passage of time, so a refreshing process—rehearsal—is needed to maintain availability" (p. 53).

The current study's focus was on the impact of time gaps or stop outs. The gaps were measured by the number of semesters that a student failed to enroll within the developmental mathematics course sequence. Adelman (2006) found that "gaps in curricular participation argue for academic administrators to identify their key gateway courses and regularly monitor participation" (p. xix). It was expected that students who complete the developmental mathematics course sequence without gaps would successfully complete college algebra at a higher rate, other factors being equal.

Purpose of the Study

The purpose of this study was to determine the correlation among the gaps within the developmental mathematics course sequence to success in college algebra. The study's focus was on those students who were first-time-in-college during the fall 2004 semester.

Based on the literature, the researcher developed two research questions:

1. What is the relationship between the number of semester gaps within the developmental mathematics course sequence and successful completion of college algebra?

2. Do the gaps before enrollment in college algebra predict difficulty in the successful completion of college algebra?

The literature review revealed that many community college students fail to complete their required developmental mathematics course sequence (Attewell, Lavin, Domina, & Levey, 2006; Calcagno, Crosta, Bailey, & Jenkins, 2006; Driscoll, 2007; Illich, Hagan, & McCallister , 2004). For this study, the developmental education course sequence for mathematics consisted of four sequential courses, ending with college algebra. Based on the results of an assessment instrument, students are placed in one of the three developmental courses or assessed as college ready. The students placed in developmental mathematics must then progress through the sequence of courses before being eligible to enroll in college algebra. This study investigated the significance of gaps or stop-outs within the developmental mathematics course sequence to college algebra.

Significance of the Study

Students requiring developmental education represent a significant portion of the student population for community colleges and graduating them is a challenge. In spite of the importance of developmental education, Levin and Calcagno (2007) found "very little rigorous research analyzing its effectiveness" (p. 7). In the review of the literature, a dearth of research was apparent in the area of remedial student success in community colleges (Illich et al., 2004; Levin & Calcagno, 2007; Attewell et al., 2006; Bailey, Jenkins, & Leinbach, 2005; Driscoll, 2007). Even less research on the factors that impede success in college algebra existed. Levin and Calcagno (2007) found "the degree to which remedial courses improve students' chances of academic success is almost

unknown because of a lack of rigorous follow-up studies" (Levin & Calcagno, 2007, p. 4). They also claimed that "little definitive evidence on the effectiveness of remedial courses and practices on persistence to graduation, quality of performance in subsequent courses, grade point average, and so on in the relevant literature" (p.4). Similarly, Hodra's 2011 study on evidence based findings for the developmental classroom concluded that "more rigorous research in the area of developmental math education is needed in order to confirm that certain practices seem promising are indeed effective in the classroom" (pp. 28-29). Hodra provided an apropos summary on the need for more research: "The academic outlook for students who enroll in developmental math courses is generally unfavorable. Improving outcomes for developmental math students will require the continued efforts of researchers and practitioners" (p. 29).

Quigley and Bailey (2003) identified various reasons why "researchers neglected community colleges" (p. 88). The main reason cited was "the cultural dominance of the four-year college model" (p. 88). Quigley and Bailey also found that

> analysts lack the cultural template within which to conceptualize the place of the community college in the system of higher education . . . most people who pursue education-research careers did not attend a community college and may have never been on a community college campus. (pp. 88-89)

Among their findings Quigley and Bailey (2003) noted that researchers are often discouraged from focusing on community colleges out of "concern about the professional status associated with studying different institutions . . . moreover, within the field of higher education, community college studies are seen as a specialty, much like student services or higher-education finance" (p. 89).

In response to the lack of research, Levin and Calcagno (2007) offered a list of questions that institutions should address in evaluating different approaches and interventions designed to prepare remedial students for college-level courses:

1. What are the background characteristics of students taking remedial courses?
2. What proportions of the students who are required to take remediation courses actually enroll and pass the course with how many attempts?
3. What levels of proficiency are exhibited by students who pass courses in each remedial subject relative to non-remedial students?
4. What kinds of courses are undertaken in the areas of initial weakness and with what results?
5. What are the completion rates in subsequent courses and baccalaureate transfer rates for students who were required to take remedial courses, and what is the typical length of time to graduation in comparison with students who did not take remediation courses?
6. What is the effect of institutional factors such as percentage of part-time faculty or the availability of professional development on the effectiveness of remedial education courses? (p. 9)

Thus, the results of this study will help augment the current body of knowledge on developmental education, specifically, on the impact that gaps in the course sequence have on college algebra success. This study incorporates components of three of Levin and Calcagno's suggestions for future research, specifically questions two, four, and five. The conclusions may assist community colleges to implement policies and practices that limit or eliminate the occurrence of gaps within the developmental mathematics course

sequence, and expand the current metrics for assessing student success beyond graduation rates.

Limitations of the Study

Although the specifics of this study limit the generalizability, it provides a framework for other researchers to replicate the study on a larger scale or for other institutions. The scope of this study is limited to first-time-in-college students who attended a rural community college in South Texas during the fall 2004 semester. The study is limited to the impact of the mathematics developmental course sequence gaps on the successful completion of college algebra. It is not intended to identify all factors that affect successful completion of college algebra. Specifically, this study is not intended to investigate the pedagogical aspect of learning algebra. Although the findings of this study may not be generalized to any other cohorts or community college, they may inform the design of future research in this field.

Definitions

Developmental/remedial course. Course designed to raise the students' skills to a college-ready level.

Developmental mathematics course sequence. A series of courses that a student must complete in preparation for college algebra, consisting of basic mathematics, elementary algebra, and intermediate algebra.

Basic mathematics. A course for students who have no admissions units in algebra or who show need for a review of the fundamentals of arithmetic.

Elementary algebra. Course for students who have no admission units in algebra or who show need for a review of the fundamentals of introductory algebra.

Intermediate algebra. A basic course in algebra which is intended for those students needing a foundation course in algebra beyond one year of high school algebra.

College algebra. Course of advanced topics in solutions of equations and inequalities. The concepts of relational function are studied with emphasis on polynomial, rational, exponential, and logarithmic functions.

FTIC. First-time-in-college, a measure utilized by higher education to denote when a student first attended college, often used to establish cohorts for longitudinal studies.

Gap. The number of semesters that a student fails to enroll in the next mathematics course.

Gateway/gatekeeper. College level courses identified as milestone/barriers to the student's academic progression.

Linked Courses. A course where students are co-enrolled in two courses simultaneously taught by the same instructor, often utilized within developmental course sequences where the highest level developmental course is combined with college algebra, the first college level course.

Successful completion. A final course grade of D or better at the Community College. With a grade of D, the student is not required to retake the course. However, a grade of C or better may be needed to transfer to a four-year institution.

Chapter 2

The purpose of this study was to determine the correlation among the gaps within the developmental mathematics course sequence to success in college algebra. The study's focus was on those students who were first-time-in-college during the fall 2004 semester. This chapter reviews the relevant research literature in four main areas: background on community colleges, issues in developmental mathematics, course sequences, and the theoretical basis for "use it or lose it."

Background of Community Colleges

Prior to the end of World War II, community colleges were virtually nonexistent. President Harry Truman's Commission on Higher Education concluded that the current number of higher education institutions in operation at the end of the war was inadequate to educate the large number of students returning to enter post secondary education (Quigley & Bailey, 2003). The Commission's first priority was the educational needs of the veterans returning from the war. The Commission found evidence from the battery of tests administered to service men and women that "half of the high-school graduates were qualified for at least two years of college-level instruction" (p. 1). In its analysis, the Commission determined that before World War II only a select number of students aspired for a college education, but afterwards, that number surged to approximately 20%. Many of these new students wanted less than a four-year education. The Truman Commission determined that a community college, an "institution designed to serve chiefly local community education needs" (Quigley & Bailey, p. 5), was necessary to address this new demand for higher education.

Hence an essential characteristic of the community college is to meet the local educational needs of the community. Quigley and Bailey (2003) summarized the commission's description on the purpose of these new institutions. The institutions must remain in tune to the needs of its community and be quick to adapt to the current educational needs of the students. They must accommodate the needs of older students and provide a mechanism for remediation, and provide programs to develop well rounded individuals, integral to live a "rich and satisfying life, part of which involves earning a living" (Quigley & Bailey, p. 6). The community college must establish a solid educational foundation. The Commission's most significant conclusion "was that a large number of two-year public institutions needed to be created. The Commission called these institutions 'community colleges'" (Quigley & Bailey, p. 1).

After Truman's 1947 Commission report, the Teacher's College at Columbia University conducted several studies regarding community colleges. It found that while community colleges resemble other colleges, many differences exist. For example, community colleges typically offer a wider variety of technical programs and are generally characterized by their less restrictive admission requirements (Quigley & Bailey, p. 38). Another significant difference noted was "admission requirements are flexible, and the heterogeneity of students is marked. These differences are all indications of the efforts community colleges are making to adapt to the problems posed, the students enrolled, and the communities served" (Quigley & Bailey, 2003, p. 38).

Quigley and Bailey (2003) found that community colleges "carry out extensive remediation for many students who leave high school without the necessary skills for college level work" (p. 69). After many years of expansion, community colleges have

evolved in an ever-changing environment. Some of the main factors that contribute to this evolution are "changes in pedagogic and production technology; state-funding policies; the expectations of students, parents, and policy makers; demographic trends; and the growth of new types of educational institutions and providers" (Quigley & Bailey, 2003, p. 70). This continued evolution provides evidence that community colleges have remained adaptable and in tune with the needs within their communities.

Another significant difference is student enrollment. Quigley and Bailey (2003) noted the "traditional conceptualization in which students attend college full-time immediately after high school and continue their enrollment uninterrupted until they graduate" (p. 74), no longer holds true. The challenge facing administrators and faculty is to continue to provide access to education while emphasizing student success outcomes to a student who does not follow the traditional enrollment patterns (Quigley & Bailey, 2003).

Issues in Developmental Mathematics

Developmental education is a key component of most, if not all community colleges. Bailey (2009) stated in a Community College Research Center Brief that "community colleges are charged with teaching students college-level material, yet a majority of their students arrive with academic skills judged too weak to allow them to engage successfully in college-level work in at least one subject area" (p. 1). A factor for the large concentration of weak academic students within community colleges may be their open admission enrollment. Attewell, Lavin, Domina, and Levey (2006) found that "about 40% of traditional undergraduates take at least one such course" (p. 886), and in a recent *Achieving the Dream* multi-state study funded by the Lumina Foundation focused

on students' success in developmental education in community colleges, Bailey, Jeong, and Cho (2008) reported that, "about 59 percent of the sample enrolled in at least one developmental course" (p. 3).

Community colleges have struggled to remediate the large number of underprepared students on their campuses; the consensus among researchers was that developmental education had reached a level of crisis (Attewell et al., 2006; Bailey, Jenkins, & Leinbach, 2005; Calcagno, Crosta, Bailey, & Jenkins, 2006). For example, in a 2007 ACT study of Texas graduates, it was determined that 62% were ready for college English composition, 41% for college algebra, 47% for college social sciences, 24% for college biology, but only 19% were ready for all four (p. 6). Levin and Calcagno (2007) proposed that the most common strategy utilized to prepare these academically challenged students for college level work by community colleges was developmental education.

According to Levin and Calcagno (2007), the students who are classified as needing remedial course work "comprise a very diverse group" (p. 2). Zeidenberg, Jenkins, and Calcagno (2007) and Kolajo (2004) agree that many entering community college students arrive unprepared in areas of reading, writing, and mathematics. Many have deficiencies from their high school studies, and many are nontraditional students with adequate preparation who just need a refresher. "Others have very poor study habits or have mild to serious learning problems that must be addressed" (Zeidenberg et al., 2007, p. 2). They found that developmental students are generally identified by various placement exams, which attempt to measure students' basic skills.

Illich, Hagan and McCallister's 2004 study found that for all remedial courses, English, reading, and mathematics, the "pass rates were lowest for remedial mathematic courses with rates ranging from 44% to 50%" (Illich et al., 2004, p. 440). Their findings revealed, "students who did not successfully complete their remedial mathematic courses under-performed in college-level courses irrespective of whether the courses were related to science, reading, or arts" (p. 448). Attewell et al. (2006) found that "students placed in remedial college courses in mathematics were somewhat more likely to drop out" (p. 892). These findings shed light on the importance of completing developmental mathematics especially as it relates to the students progression toward degree completion.

Additionally, Driscoll (2007) discovered that a vast majority of students enter community college with the "goal of transferring to a four-year college to earn a bachelor's degree, but only a minority make it past the first semester with their goals intact" (p. 1). Driscoll's study also noted that "most either leave school or lower their educational goals before the beginning of their second semester" (p. 2). The first semester proved to be crucial in the likelihood that the student would succeed in achieving his or her goals. Driscoll claimed that "students whose first academic experience in college is positive and successful are more likely to persist toward their goals than those who have negative initial experiences" (p. 4). Adelman (2006) also found that the students' performance during their first years of attendance is a crucial factor in graduation. Adelman's 2006 study found that earning "less than 20 credits by the end of the first calendar year of enrollment . . . is a serious drag on degree completion" (p. xx). Thus, the first collegiate experience for students often determines their ultimate academic fate.

Another factor detrimental to graduation identified in the literature search includes developmental mathematics. Calcagno, Crosta, Bailey, and Jenkins (2006) studied the impact of enrolling in a developmental mathematics course on graduation for both older students and the traditional younger students. Their study found that students who were enrolled in remediation had a significantly lower probability of graduating. Younger students who enrolled in remediation courses were 42% less likely to graduate than those who did not. Older students reduced their probability of graduating by 23% if they required remediation. An important finding in the study proved to be that passing the first college-level mathematics course was more important for younger students. Calcagno, Crosta, Bailey, and Jenkins's (2006) findings supported efforts to help remedial students take and pass initial-level college mathematic courses, since passing these "gatekeepers" substantially increase the chances that students succeed (Adelman, 2006). Using the National Education Longitudinal Study (NELS) by Attewell, Lavin, Domina, and Levey (2006), Bailey (2009) found that "degree completion for remedial students is also rare. Less than one fourth of developmental education community college students in the NELS sample completed a degree or certificate within eight years of enrollment" (p. 2).

In a 2007 study, *Algebra: Gateway to a Technological Future* published by the Mathematical Association of America, researchers found that "nationwide more than 45% of students enrolled in College Algebra either withdraw or receive a grade of D or F" (p. 34). As a result of the study, the working team recommended that institutions refocus college algebra to include more modeling, in-class activities, and content relevant

to outside mathematics. The research team also recommended that future research include

> in-depth, multi-year, longitudinal research projects to study all aspects of the development and implementation of refocused College Algebra with an emphasis on determining the impact of well-designed and well-supported refocused College Algebra courses on student achievement and understanding as well as persistence in future mathematically-related coursework. (p. 35)

This recommendation supports the need for additional research that expands the scope of success beyond course outcome to subsequent student success.

The literature search validated the conclusions of Bailey, Jenkins, and Leinbach (2005); "the educational effectiveness of community colleges is under new scrutiny as a result of both a federal government focus on accountability of higher education institutions and greater competition for the state funds traditionally directed to the colleges" (p. 1). A driving force behind this new scrutiny is the very low completion rates for community colleges overall (Bailey, Jenkins, & Leinbach, 2005). In addition, colleges

> must also know what factors contribute to milestone achievement. Some factors that affect student success, such as a student's educational background, demographic characteristics, and outside demands on time are obviously beyond a college's control. However, other factors over which institutions have more control also contribute to or detract from student achievement. For example, during a student's enrollment, particular course completions or other educational

> accomplishments can provide 'momentum' that propels students toward the achievement of milestone events. (Leinbach & Jenkins, 2008, p. 2)

Jenkins (2006) found that the "key to a college's effectiveness is not whether it adopts particular policies or practices, but how well it aligns and manages all of its programs and services to support student-success" (p. 3-4).

Course Sequences

The next area of the literature review is focused on the developmental course sequence, when "students are referred to a sequence of developmental courses of increasing difficulty in one subject area because their skills are considered to be more than one level below college-entry level" (Bailey, 2009, p. 1). Bailey's study revealed several troubling trends regarding developmental education. He found that "some students never even begin their developmental course sequence" (p. 1-2). Also alarming, Bailey found that

> only 44 percent of those referred to developmental reading completed their full sequence, and only 31 percent of those referred to developmental math completed theirs. Further, the more courses in the referred sequence, reflecting a greater skill deficiency, the more likely students were to fail to complete it. (p. 2)

The lack of progression within the developmental mathematics course sequence was further investigated by Bailey and Cho (2010) in a subsequent study that found, "the sequence of courses is often too complicated and takes too long" (p. 2). They recommend that institutions address the strategies employed to enroll the students in these courses and assist them "bridge the gap between courses" (p. 2). Levin and Calcagno (2007) found consensus among educational researchers that "skills taught in

isolation are less likely to be applied productively to further coursework" (p. 6). They found many models to accomplish this, including "adjunct courses, tandem classes, paired courses, packaged courses, linked courses, and, in a variant form, supplemental instruction and learning communities" (p. 6). These models link the basic skills subject to a credit-bearing course.

Pima Community College piloted an experimental algebra design that linked two remedial mathematic courses and emphasized reading and writing in an effort to improve students' success in college algebra (Everett-Hayes, 2006). Another form of a paired or linked course format is an accelerated learning program or ALP, which is characterized by the following:

> Students placed into upper level developmental courses are "mainstreamed" into college-level courses in that subject, and are simultaneously enrolled in a companion ALP course (taught by the same instructor) that meets in the class period immediately following the college-level class. The aim of the ALP course, which has a small number of students, is to help students maximize the likelihood of success in their first college-level course and to speed up their progress through the developmental sequence. (Bailey & Cho, 2010, p. 4)

These course models support Scott-Clayton's (2011) structure hypothesis, which states that students need more structure to be successful in community colleges "with relatively little room for individuals to deviate on a whim – or even unintentionally – from paths toward completion, and with limited bureaucratic obstacles for students to circumnavigate" (p. 1).

Bailey, Jeong, and Cho (2010) argue that "concerted efforts should be made to encourage students who complete one course in their sequence to go on to the next one" (p. 6). Some of these changes include "abandoning the semester schedule to prevent gaps between courses, or registering and scheduling students for the next course in a sequence while they are still in the previous course" (p. 6). The need for reforming the course sequence was summarized by Scott-Clayton's (2011) statement that an integral component of student success is "the structure, or lack thereof, of student pathways from initial entry through completion. For many students at community colleges, finding a path to degree completion is the equivalent of navigating a river on a dark night" (p. 1). The literature on course sequences supports the need for additional research and changes to the mechanics of providing developmental mathematics.

Theoretical Basis

The next area of the literature review is focused on the theoretical basis supporting the hypothesis that gaps within the developmental course sequence negatively impact the successful completion of college algebra. This review includes an analysis of the effects that time gaps may have on learning, based on behaviorist, cognitive, and constructivist theories. It was found that a dearth of research exists with regards to the specific impact of time gaps on learning.

In early behavioral learning literature, before 1930, Edward Thorndike explained the learning process with three laws of learning: laws of readiness, exercise, and effect. The law of exercise included two parts: law of use and disuse (Hergenhahn & Olson, 2005). The law of use in essence states, "connections between stimulus and a response are strengthened as they are used. In other words, merely exercising the connection

between a stimulating situation and a response strengthens the connection between the two" (Hergenhahn & Olson, p. 61). Conversely, the law of disuse states, "connections between situations and responses are weakened when practice is discontinued or if the neural bond is not used" (p. 61).

Guthrie (as cited in Hergenhahn and Olson, 2005), believed that Thorndike had over-complicated his theories on learning, and offered the law of contiguity, which simply stated is "to say that if you did something in a given situation, the next time that you are in that situation, you will tend to do the same thing" (p. 212). Hergenhahn and Olson (2005) state that "there is nothing new about the law of contiguity as a principle of learning. . . . It goes all the way back to Aristotle's laws of association" (p. 212).

Guthrie explained the principle of one-trial learning as "learning is the result of contiguity between a pattern of stimulation and a response, and learning is complete (the association is at full strength) after only one pairing between stimuli and the response" (p. 213), as cited in Hergenhahn and Olson (2005). The recency principle completes the principles of contiguity and one-trial learning in that "the response performed last in the presence of a set of stimuli will be that which will be done when that stimulus combination next occurs" (Hergenhahn & Olson, 2005, p. 213).

Does practice make perfect? In response to this question Guthrie explained the differences between acts and movements. "Movements are simple muscle contractions; acts are made up of a large number of movements [and] . . . a skill is made up of many acts" (as cited in Hergenhahn & Olson, p. 215). Therefore learning a skill, such as shooting a basketball in the rim consists of "learning thousands of associations between specific stimuli and specific movements" (p. 215), as cited in Hergenhahn and Olson.

According to Ericsson and Lehmann (1996), the response to the question, does practice make perfect, the response is yes. They found that "experts' knowledge and task-specific reactions must have been acquired through experience" (p. 274). Their study on expert performance found that "expert performance results from extended, deliberate practice" (p. 297).

Another argument for the utility of practice is evident in the realm of acquiring a second language. Dekeyser (2010) argued that "retrieval of knowledge in the course of language processing is a complex skill that requires much practice, and the concept applies to the lexicon as well as to grammar" (p. 157). Fang's (2010) study on cross-culture communication found that for learning a second language, "syntactically complex input can be made comprehensible with the use of repetition, [and] expansion" (p. 15). This finding supported the hypothesis that practice is important.

How does Guthrie's, as cited in Hergenhahn and Olson (2005), and Ericsson and Lehmann's (1996) approach to learning and mastering a skill transfer to learning college algebra? One example of this transfer may be inferred in the U.S. Department of Education *WWC Intervention Report on the Saxon Math Textbook*, "Saxon Math is a textbook series . . . based on incremental development and continual review of mathematical concept to give students time to learn and practice concepts" (U.S. Department of Education, 2010, p. 1). The importance of incremental learning and repetition was offered by Guthrie, as cited in Hergenhahn and Olson (2005):

> Learning occurs normally in one associative episode. The reason that long practice and many repetitions are required to establish certain skills is that these really require many specific movements to be attached to many different stimulus

situations. A skill is not simple habit, but a large collection of habits that achieve a certain result in many and varied circumstances (p. 215).

The process by which one learns to compose a document on a keyboard can also be transferred to learning algebra. Hergenhahn and Olson described the process by which a letter written on paper corresponds to a specific key on the keyboard, followed by the next letter and so on. Then one proceeds to learn the numbers, capital letters, under different lighting conditions, different angles and so forth. It is not until "all these responses have been learned, we say the person has become proficient. Thus, a skill such as word-processing (or typing) involves an enormously large number of specific S-R [stimulus-response] connections, each of which is learned in a single trial" (Hergenhahn & Olson, 2005, p. 216). Given this example, the same may be said of learning algebra, which is an incremental learning of processes.

Along this same line of theory, Bigge and Shermis (1992) elaborated on the effect of Skinner's extinction of learned behavior. Extinction refers to learned behavior that is lost as "result of its ceasing to receive reinforcement on repetition" (p. 109). It is important to note that, "when unaccompanied by extinction, forgetting takes place very slowly if at all . . . forgetting is the losing of a habit through passage of time, extinction requires that the response be emitted without reinforcement" (Bigge & Shermis, 1992, p. 109). The theory on extinction is relevant, "since behavior during extinction is a result of the conditioning that preceded it, extinction occurs quickly when only a few incidents of a given response have been reinforced and is greatly protracted when there has been a long history of reinforcement" (Bigge & Shermis, 1992, p. 109). Therefore, extinction is reduced in the presence of solid reinforcement, and extinction can be avoided through

solid reinforcement in the developmental mathematics course sequence, that is without any gaps.

Another example of such a transfer of theories is evidenced in Grippin and Peters' (1984) discussion of motor learning and performance by behaviorists and cognitivists. They found that "within each approach discrete aspects of motor learning and performance have been studied, revealing differences between acquisition and performance, between description and explanation, between adult learning and child learning" (p. 104). When distinguishing between massed and distributed practice, Grippin and Peters found that behaviorists posit that "in general, distributed practice is better than massed" (p. 105). Grippin and Peters (1984) agree that "retention of a well-practiced skill is very high" (p. 106).

After 1930, Thorndike discarded the law of exercise, but "maintained that practice leads to minor improvement and that lack of practice leads to slight forgetting" (Hergenhan & Olson, p. 67). Omrod (2008) stated that "psychologists have come to believe that information can gradually fade away, or **decay**, and eventually disappear from memory altogether" (p. 294). This decay affects information in various degrees. Omrod found that specific details fade more quickly than "underlying meaning, or gist" (p. 294). Another explanation for forgetting information is failing to store or consolidate (Omrod, 2008). This is the case when information was not processed sufficiently to be stored into long-term memory.

Thorndike's law of exercise, sometimes labeled "use-disuse" (Grippin & Peters, 1984, p. 33), argued that if a skill was not used in a long time it would be expected that the skill would be lost; however, the literature contains "much evidence, that there are

hundreds of things that we remember in spite of years of disuse" (p. 33-34). In the discussion of use-disuse, Grippin and Peter (1984) see the difference in loss of skills depending on how strong the learning was originally, "it seems then that if something is well 'stamped in' as Thorndike would say, even long periods of disuse will not disturb it" (p. 34).

From a cognitive learning theory perspective, Nairne's (2002) work on short-term memory found that "virtually all complex cognitive activities—reading, reasoning, problem solving – require access to intermediate steps" (p. 54). This process is a result of activation, "a mnemonic property that keeps information in an immediate accessible form" (p. 54). He further stated that "permanent knowledge is activated, as a byproduct of on-line cognitive processing, and comes to reside 'in' short-term (or working) memory" (p. 54). Thus, activation is the key to retaining the information and counteracting decay: "activation is assumed to be fragile, however, and it can be quickly lost—through the operation of *decay*—in the absence of rehearsal" (p. 54).

Constructivist learning theory was emphasized in Ormrod's (2008) conclusion that solving algebraic problems involves the construction of entirely new memories, assuming the student has learned or "stamped in" the appropriate algebraic principles. Omrod (2008) offers the following example to illustrate this perspective (p. 291):

> Consider this arithmetic problem:
>
> $$\frac{1}{2} \text{ X } 0 = ?$$
>
> You may never have been given the answer to this specific problem, yet you no doubt learned long ago that anything times zero equals zero. Hence you are able to construct the correct answer $\frac{1}{2} \text{ X } 0 = 0$

Omrod stated that this ability of "constructive retrieval enables individuals to produce information beyond what they have specifically stored" (p. 291). In essence, the student learns a general rule and then applies the rule each time this type of problem is presented. According to Bottge (1999), "the theoretical underpinnings of mathematics problem solving derive from cognitive psychology. There are two distinct aspects of the problem solving: skill acquisition and generalization" (p. 82). The literature provided the theoretical basis that gaps that occur during the developmental stage of learning algebra contribute to the decay of the algebraic concepts previously acquired. The gaps occur before the students reach the level of mastery.

The literature review provided a history on the formation and role of community colleges, and their need to remain adaptable to their communities. Next the review addressed issues in developmental mathematics, with the general consensus that it is in a state of crisis. The literature review then explored the course sequences and how they impact developmental mathematics. Researchers concluded that there is a need for additional research and reform in the area of course sequences. The final section of the review provided the theoretical basis that supports the hypothesis that gaps within the developmental course sequence can affect college algebra completion.

Chapter 3

This study was designed to follow the first-time-in-college (FTIC) students' enrollment in developmental mathematics courses beginning with the fall 2004 semester through the second summer semester of 2010, a period of six years. The fall 2004 cohort was selected at the Community College to determine the correlation between the gaps in the developmental mathematics course sequence and successful completion of college algebra. This chapter describes the research design, subjects, analysis, and operational definitions for this study.

Research Design

According to Creswell's (2005) criteria for correlational studies, an ex-post-facto correlational design would provide an appropriate framework for the study. Creswell (2005) stated "in correlational research designs, investigators use the correlation statistical test to describe and measure the degree of association (or relationship) between two or more variables or sets of scores" (p. 325). In this study the primary variables were College Algebra Success, Total Semester Gaps, College Algebra Attempts, Total Terms Enrolled to College Algebra, and Initial Developmental Mathematics Placement. The variable College Algebra Success was coded as a dichotomous variable where 1 indicated a successful completion and 0 a failure. Total Semester Gaps were calculated by converting each semester to an ordinal number between one and twenty-four, each number assigned recorded distance in semesters from fall of 2004. Next a formula was used to calculate the specific location (between which two courses) of the gap. After each individual gap was calculated, they were combined to arrive at the Total Semester Gaps variable. The variable Total Terms to College Algebra was recorded as the

numerically converted semester term that a student successfully completed college algebra. The last variable, Initial Developmental Mathematics Placement, codes each student into one of four levels. The first level denotes students placed into the lowest level of the developmental mathematics course sequence, and the fourth level denotes that students were placed as college ready. The college ready students were eligible to enroll directly in college algebra without any developmental course requirements.

Relationships between the discrete variable, College Algebra Success, and the independent predictor variables of Total Semester Gaps, College Algebra Attempts, Total Terms to College Algebra, and Initial Developmental Mathematics Placement were tested via a binary logistic regression. The regression model was utilized to determine if the independent variables increased the ability to accurately predict a student's success in college algebra. The model was assessed for goodness-of-fit via the omnibus tests of model coefficients, -2 log likelihood, and the Hosmer and Lemeshow test in accordance with Tabachnick and Fidell (2007).

"Three types of tests are available to evaluate the contribution of an individual predictor to a model: (1) the Wald test, (2) evaluation of the effect of omitting a predictor, and (3) the score (Lagrange multiplier) test" (Tabachnick & Fidell, 2007, p. 459). For this study, each individual variable contribution to the model was evaluated with the Wald statistic and the odds ratio.

Subjects

The study follows a cohort of FTIC students who were enrolled in the fall of 2004. This cohort was identified utilizing the Community College's Estudias® by

Zogotech data warehouse software. The cohort size was evaluated for this research design according to MedCalc Software (2011) criteria that

> sample size calculation for logistic regression is a complex problem, but based on the work of Peduzzi et al. (1996) the following guideline for a minimum number of cases to include in your study can be suggested. Let **p** be the smallest of the proportions of negative or positive cases in the population and **k** the number of covariates (the number of independent variables), then the minimum numbers of cases to include is:
>
> N = 10 k / p. (p. 5)

For this study the smallest proportion (**p**) of negative or positive cases was determined to be 30%, and includes four covariates (**k**). Thus according to the suggested formula the minimum required cases are 140. In this study $N = 885$, which exceeds the minimum required cases; therefore, the sample size is deemed adequate to perform the logistic regression analysis with four predictor variables. For the binary correlation analysis, Creswell (2005) stated that a sample size of $N = 30$ is satisfactory for the use of correlational statistics. The sample size $N = 885$ exceeds the minimum sample size required.

Permission to conduct the study was obtained from the Community College. The researcher secured approval from the institutional review board, assuring that care be taken to safeguard personally identifiable student information prior to any collection of student data. The data was collected and analyzed during 2011.

Analysis

After the information was gathered, descriptive analysis of the data was performed with the use of the college's Estudias® data warehouse. Estudias® was utilized to conduct preliminary cohort analysis of the group. One such descriptive analysis identified how many students in the cohort had completed each of the subsequent developmental courses, completed college algebra, and graduated. Another analysis reviewed the data and calculated the gaps and their location within the developmental mathematics course sequence. Additionally, the data was disaggregated for further analysis.

The raw data was extracted from Estudias® and entered into SPSS statistical software, version 19. The data was cleaned and missing data accounted for. Descriptive data was analyzed, tested for central tendencies, variability, and tests of relative standing. Data was also analyzed for any other assumptions necessary for the appropriate statistical test. Data analysis included a correlation matrix, a determination of the direction of the association, as well as a logistic regression.

The data analysis included exploratory correlations among additional variables included in the data set. Correlations between each specific gap and College Algebra Success were found to be not statistically significant. Further analysis included correlations between the study's primary variables and grades in college algebra; these correlations also proved to be not statistically significant.

Operational Definitions

The study included demographic, descriptive, and other variables. The primary variables in the study were College Algebra Success, Total Semester Gaps, College

Algebra Attempts, Total Terms to College Algebra, and Initial Developmental Mathematics Placement. The study also incorporated secondary variables of Gap 1, Gap 2, Gap 3, and Gap 4.

College Algebra Success was utilized to record both when and if the student completed college algebra. Although many researchers have used the term successful completion to denote a grade of C or better (Adelman, 2006), for this study a grade of D was included as a successful completion. The decision to include the D grade in the study was influenced by the Community College academic policy that requires students to maintain a cumulative C average on all college level courses.

The variable Total Semester Gaps represented the cumulative time gaps as measured by semesters that a student failed to enroll in the developmental course sequence prior to the successful completion of college algebra. In calculating this variable, allowances were made for students who either enrolled in and dropped courses, or attempted and failed courses. The Total Semester Gaps counted a failed courses attempt as an enrollment, and therefore, no gaps were recorded in those instances.

College Algebra Attempts was a variable within the data set that tracked each different attempt at college algebra. The data included similar variables for each of the courses within the sequence. However, the variables for the course attempts were not statistically significant to college algebra success. College Algebra Attempts was a measure that recorded the level of student persistence after failing the course initially.

Total Terms to College Algebra was another variable utilized to measure students' persistence. This variable was recorded by identifying the semester that a student completed college algebra. The semester was converted to its numeric

representation; for example, 2004 Fall = 1, 2005 Spring = 2, through 2010 Summer II = 24.

The variable Initial Developmental Mathematics Placement measured students' initial algebra skills. The variable was used as a controlling factor. For example, if a student was placed in Level 1, that would require the student to enroll a minimum of three semesters before being college ready. A student placed in Level 4 would be eligible to enroll in college level courses immediately.

The secondary variables of Gap 1 through Gap 4 measured the number of semesters between each specific developmental course in the sequence. For example, Gap 1 recorded the number of gaps between fall 2004 and enrollment in Math 0301, the lowest level in the course sequence. Gap 2 recorded the gaps between completion of Math 0301 and enrollment in Math 0302. Gap 3 recorded the gaps between completion of Math 0302 and enrollment in Math 0303. Gap 4 recorded the gaps between completion of Math 0303 and enrollment in Math 1314, college algebra. These variables were utilized to determine if the location of the gaps had a different impact on predicting College Algebra Success. The cumulative total of gaps 1 through 4 was recorded as the variable Total Gaps.

The following figure provides a visual representation of the enrollment pattern and corresponding coding of the variables for one student. The student was initially placed in Level 2, enrolled the first semester (2004 fall) in Math 0302 (Level 2 course). Then the student failed to enroll in the subsequent three semesters. Subsequently, the student attempted Math 0303 (Level 3 course) in semester 5 (2005 fall), failed it, reattempted and successfully completed it in semester 6 (2006 spring). The student again

failed to enroll in the two subsequent semesters and attempted Math 1314 (College Algebra/Level 4 course) in semester 9 (2006 fall) but failed the course. The student finally reattempted and successfully completed Math 1314 in semester 10 (2007 spring).

Year	2004	2005				2006				2007
Semester	Fall	Spring	Summer I	Summer II	Fall	Spring	Summer I	Summer II	Fall	Spring
Term Index	1	2	3	4	5	6	7	8	9	10
Student Data	L2 – L2-Pass	L3 Gap = 3			L3 – L3-Fail	L3 – L3-Pass	L4 Gap = 2		L4 – L4- L4-Fail	L4 - Pass

Figure 1. Student Enrollment Data

Presents an example of a student's developmental mathematics course sequence enrollment information from data collected.

Initial Placement = 2 (Level 2)

Total Gaps = 5 (Level 3 Gap = 3) + (Level 4 Gap = 2)

Total Terms Enrolled = 10

College Algebra Attempts = 2

College Algebra Success = Yes

L2 = Math 0302

L3 = Math 0303

L4 = Math 1314 (College Algebra)

Chapter 4

The purpose of this study was to determine the correlation among the gaps within the developmental mathematics course sequence to success in college algebra. The study's focus was on those students who were first-time-in-college during the fall 2004 semester. The two research questions were: (a) what is the relationship between the number of semester gaps within the developmental mathematics course sequence and successful completion of college algebra? And (b) does the gap before enrollment in college algebra predict successful completion of college algebra? In order to answer the research questions, spearman rho correlations were investigated, and logistic regressions were analyzed.

This chapter reveals results to the research questions, descriptive analysis, and inferential results of logistic regressions. Data from 885 students, first-time enrolled in college during the fall 2004 semester were available for analysis: 363 students successfully completed college algebra, and 522 students did not successfully complete the course. The descriptive analysis included an analysis of the semester gaps and an analysis of course progressions. The course progression analysis included an investigation of the number of students who completed the appropriate course but failed to enroll in the subsequent course along with those students who attempted the course and failed to complete it successfully. It is apparent from Table 3 that a number of students successfully completed their first required course, but failed to enroll in the subsequent course. The rate at which Level 3 students failed to progress was approximately three times the rate than from Level 1 to Level 2 students.

Table 3

Analysis of Noncompletions and Failed to Enroll in Subsequent Course

Initial Placement Level	Attempts	Completed Progressed to Next Course	Completed Failed to Progress to Next Course	Did Not Complete	Total Sequence Drop Outs
Level 1	1	114	28	67	
	2	17	2	12	
	3+	10	1	8	188
Level 2	1	79	23	68	
	2	25	3	14	
	3+	12	6	10	124
Level 3	1	77	80	41	
	2	6	3	11	
	3+	7	0	7	142
Level 4	1	170		45	
	2	8		8	
	3+	5		5	58

In summary, Table 3 shows that, out of 237 Level 1 students, 141 progressed to the next course, while 188 never continued in the mathematics course sequence. For the 238 Level 2 students, 116 progressed to the next course, while 124 never continued in the mathematics course sequence. And for the 152 Level 3 students, 90 students progressed to the next course, while 142 failed to continue to the next course. An important observation of this descriptive data: 146 students, or 23%, of these students failed to complete because they simply failed to enroll in the subsequent course.

Table 4 below provides descriptive information regarding an analysis of the Total Gaps presented by the students' Initial Developmental Mathematics Placement. The table illustrates that although the mean gap appears low, the standard deviation was approximately four semesters in most cases, and a number of students completed college algebra with up to twenty total gaps.

Table 4

Analysis of Semester Gaps

	Mean Gap	Standard Deviation	Maximum	Cumulative Gaps
Level 1	1.8	3.9	20	423
Level 2	1.5	3.3	19	551
Level 3	1.9	3.9	21	696
Level 4	2.7	4.2	20	1304

Note. Gap = semesters

A direct logistic regression analysis was performed on College Algebra Success as the outcome variable with the predictor variables of Total Semester Gaps, College Algebra Attempts, Total Terms Enrolled to College Algebra, and Initial Developmental Mathematics Placement. Analysis was performed using SPSS binary logistic regression. A series of logistic regressions was performed to ascertain the impact of semester gaps. The first logistic regression used the variable Initial Placement as the block one variable, a controlling variable, and the variable Total Gaps (cumulative semester gaps) to measure the gap impact. Subsequent logistic regressions analyzed the impact of the gaps by selecting a single Initial Placement Level (1-4), and alternating the variable Total Gaps with each individual level gap. The first results are presented for all students, which encompass all placement levels, with total gaps then individual gaps. The following logistic regression results are presented for students initially placed in Level (1-4) with the variable Total Gaps then individual gaps.

Analysis on All Placement Levels – Total Gaps

Table 5 illustrates the correlations between the dependent variable College Algebra Success and the four independent predictor variables. Table 5 reveals that all predictor variables were statistically significant at the $p < 0.01$ level. Three of the

variables have positive correlations to College Algebra Success. Total Semester Gaps was the only variable that was negatively correlated to College Algebra Success. The variable Total Semester Gaps was significantly correlated to College Algebra Success, -0.30 at $p < .01$, but it was the weakest of the correlations.

Table 5

Intercorrelations for College Algebra Success and Four Other Measures

	Measure	1	2	3	4	5
1.	Math 1314 success	--				
2.	Initial Placement Level	.48**	--			
3.	Math 1314 attempts	.70**	.54**	--		
4.	Total Terms Enrolled	.53**	.18**	.51**	--	
5.	Total Semester Gaps	-.30**	-.30**	-.03	.37**	--

Note. ** Spearman's rho correlations significant at $p < .01$
Math 1314 = College Algebra

A test of the full model with all four predictors against a constant-only model was statistically significant, χ^2 (4, N = 885) = 726.194, $p < .001$, indicating that the predictors, as a set, reliably distinguished between success and failure in college algebra. The classification by the model as illustrated in Table 6 was above average, with 89.3% of successful completion and 92.9% of non-successful completions predicted, for an overall prediction success rate for the model of 91.4% compared to 59.0% without it.

Table 6

Classification Table for - Total Gaps

	Observed	Predicted Correct Percentage Block 0	Block 1	Block 2
Fail	522	100%	71.5%	92.9%
Pass	363	0%	71.9%	89.3%
Overall Percentage		59%	71.6%	91.4%

Block 0 included no variables, and the percentage was calculated on the assumption that all students would fail. Block 1 included the variable Initial Placement Level, which improved the classification percentage by 12.6%. Block 2 utilized the variables Total Gaps, Total Terms Enrolled, and College Algebra Attempts, to form a predictive equation for College Algebra Success and improved the classification percentage to 91.4%.

The Omnibus Tests of Models results were statistically significant, χ^2 (4, N = 885) = 726.194, $p < .001$, which indicated that the model performed better than with no predictors included. In other words the use of the predictors in the equation resulted in a better prediction mechanism than if left to predict by chance. However, the Hosmer and Lemeshow test did not support this with a significance level of less than .05, χ^2 (8, N = 885) = 58.915, $p < .001$. The model summary provides an indication of the amount of variation in the dependent variables as explained by the model. This measure is important to discern the amount of influence the variables have on College Algebra Success. In this case the Cox & Snell R Square and the Nagelkerke R Square values, .560 and .755, respectively, indicate the amount of variation. This suggested that 56.0% to 75.5% of the variability is explained by this set of predictors.

Table 7 shows regression coefficients, Wald statistics, odds ratio, and standard errors for each of the four predictors. According to the Wald criterion, the predictor, Terms Enrolled, had the most effect on predicting College Algebra Success, followed by total gaps then course attempts and placement level. All four predictors contributed significantly to the predictive ability of the model.

Table 7

Summary of Logistic Regression Analysis Predicting College Algebra Success

Variable	*B*	*SE*	Odds ratio	Wald statistic
Placement Level	0.57	0.12	0.57	23.21
Total gaps	-0.49	0.05	0.61	108.60
College algebra attempts	1.55	0.18	0.21	71.51
Terms enrolled	0.72	0.06	0.49	137.42
Constant	-4.83	0.44	0.01	118.24

$p < .01$

The beta values from the summary of logistic regression in Table 7 provided the necessary information to construct the predictive equation for the model. The beta values and student data from the example provided in Figure 1 at the end of Chapter 3 can be used to demonstrate the predictive equation. This predictive equation is based on the logistic regression that includes all students, Levels 1-4. The result of the predictive equation provides the probability of student success in college algebra.

Initial Placement = 2 (Level 2)

Total Gaps = 5 (Level 3 Gap = 3) + (Level 4 Gap = 2)

Total Terms Enrolled = 10

College Algebra Attempts = 2

Where,

$$probability(success) = \pi$$

And,

$$\pi = \frac{e^{\alpha + B_1(InitialPlacement) + B_2(TotalGaps) + B_3(TermsEnrolled) + B_4(Attempts)}}{1 + e^{\alpha + B_1(InitialPlacement) + B_2(TotalGaps) + B_3(TermsEnrolled) + B_4(Attempts)}}$$

Then, by substituting the constant and B from the predictive equation from Table 7 the following predictive equation results:

$$\pi = \frac{e^{-4\ 83 + (\ 57)(InitialPlacement) + (-\ 49)(TotalGaps) + (\ 72)(TermsEnrolled) + (1\ 55)(Attempts)}}{1 + e^{-4\ 83 + (\ 57)(InitialPlacement) + (-\ 49)(TotalGaps) + (\ 72)(TermsEnrolled) + (1\ 55)(Attempts)}}$$

Then, by substituting the student data from Figure 1 at the end of Chapter 3, all the values in the predictive equation are presented.

$$\pi = \frac{e^{-4\ 83 + (\ 57)(2) + (-\ 49)(5) + (\ 72)(10) + (1\ 55)(2)}}{1 + e^{-4\ 83 + (\ 57)(2) + (-\ 49)(5) + (\ 72)(10) + (1\ 55)(2)}}$$

$$\pi = \frac{64.07}{65.07}$$

Then,

$$\pi = .98$$
$$probability(success) = 98\%$$

Thus, in this example, the predictive equation derived from the binary logistic regression model predicts that the student has a 98% likelihood of college algebra success. A closer analysis of the predictive equation reveals that the impact of the five gaps were offset by the positive effect of the Terms Enrolled and the two attempts at college algebra. This

data provides for the use of alternative strategies to assist current students who have already accumulated gaps in the system. For example, beyond addressing any additional gaps, institutions could enhance retention efforts to keep students engaged and moving toward college algebra.

Analyzing the predictive equation is one mechanism to evaluate the impact of each variable, another "strategy is to evaluate odds ratio: The statistically significant predictors that change the odds of the outcome the most are interpreted as the most significant" (Tabachnick & Fidell, 2007, p. 469). When evaluating odds ratio, the "farther the odds ratio from 1, the more influential the predictor" (Tabachnick & Fidell, 2007, p. 469). The magnitude of the odds ratio for total gaps of 0.61, with a 95% confidence interval of .558 and .671, as evidenced in Table 7, indicated that a student was 1.64 times as likely to fail with each gap, all other factors being equal. Therefore, it can be concluded that zero gaps would have a positive impact on a student by eliminating a negative factor from the predictive equation. Conversely, each additional gap increased the likelihood of failure by 1.64 times. In order to further investigate the impact of the gaps on the successful completion of college algebra, additional binary regressions analysis were performed.

Analysis on All Placement Levels – Individual Gaps

A test of the full model with predictors against a constant-only model was statistically significant, χ^2 (7, N = 885) = 569.209, p < .001, indicating that the predictors, as a set, reliably distinguished between success and failure in college algebra. The predictors in this model included Total Terms Enrolled, College Algebra Attempts, L1 Gap, L2 Gap, L3 Gap, and L4 Gap. The individual level gaps were substituted for the

variable Total Gaps in order to ascertain if any individual level gap was more significant than another. The classification by the model as illustrated in Table 8 was above average, with 87.6% of successful completion and 87.5% of unsuccessful completions predicted, for an overall prediction success rate for the model of 87.6% compared to 59.0% without it.

Table 8

Classification Table

		Predicted Correct Percentage		
	Observed	Block 0	Block 1	Block 2
Fail	522	100%	71.5%	87.5%
Pass	363	0%	71.9%	87.6%
Overall Percentage		59.0%	71.6%	87.6%

Block 0 included no variables, and the percentage was calculated on the assumption that all students would fail. Block 1 included the variable Initial Placement Level. Block 2 utilized the variables L1 Gap, L2 Gap, L3 Gap, L4 Gap, Total Terms Enrolled, and College Algebra Attempts, to form a predictive equation for College Algebra Success.

The Omnibus Tests of Models results were statistically significant, χ^2 (7, N = 885) = 569.209, $p < .001$, which indicated that the model performed better than with no predictors included. In other words, the use of the predictors in the equation results in a better prediction mechanism than if left to predict by chance. However, this model with the individual gaps did not perform as well as the model with the variable Total Gaps. The model summary provides an indication of the amount of variation in the dependent variables as explained by the model. This measure is important to discern the amount of

influence the variables had on College Algebra Success. In this case the Cox & Snell R Square and the Nagelkerke R Square values, .474 and .640, respectively, indicate the amount of variation. This suggested that 47.4% to 64.0% of the variability was explained by this set of predictors.

Table 9 shows regression coefficients, Wald statistics, odds ratio, and standard errors for each of the four predictors. According to the Wald criterion, the predictor, Terms Enrolled, had the most effect on predicting college algebra success, followed by College Algebra Attempts and Placement Level. The individual gap that had the most effect on predicting college algebra success was the L4 Gap (last gap). All predictors contributed significantly to the predictive ability of the model.

Table 9

Summary of Logistic Regression Analysis Predicting College Algebra Success

Variable	*B*	*SE*	Odds ratio	Wald statistic
Placement Level	0.652	0.11	1.92	37.80
L1 Gap	-0.21	0.11	0.81	3.50
L2 Gap	-0.28	0.07	0.75	14.50
L3 Gap	-0.17	0.05	0.84	12.46
L4 Gap	-0.15	0.03	0.86	22.75
College algebra attempt	1.57	0.20	4.79	64.54
Terms enrolled	0.39	0.04	1.47	104.33
Constant	-4.94	0.40	0.01	153.52

$p < .01$

Table 9 provides the necessary components to construct the predictive equation for the model. The result provided the probability of student success in college algebra. The following predictive equation was derived from the Table 9 data and student data presented in Figure 1 at the end of Chapter 3.

Initial Placement = 2 (Level 2)

Total Gaps = 5 (Level 3 Gap = 3) + (Level 4 Gap = 2)

Total Terms Enrolled = 10

College Algebra Attempts = 2

Where,

$$probability\ (success) = \pi$$

And,

$$\pi = \frac{e^{\alpha + B_1(InitialPlacement) + B_2(L1Gaps) + B_3(L2Gaps) + B_4(L3Gaps) + B_5(L4Gaps) + B_6(TermsEnrolled) + B_7(Attempts)}}{1 + e^{\alpha + B_1(InitialPlacement) + B_2(L1Gaps) + B_3(L2Gaps) + B_4(L3Gaps) + B_5(L4Gaps) + B_6(TermsEnrolled) + B_7(Attempts)}}$$

$$\pi = \frac{e^{-4.94 + (.65)(2) + (-.21)(0) + (-.28)(0) + (-.17)(3) + (-.15)(2) + (.39)(10) + (1.57)(2)}}{1 + e^{-4.94 + (.65)(2) + (-.21)(0) + (-.28)(0) + (-.17)(3) + (-.15)(2) + (.39)(10) + (1.57)(2)}}$$

$$\pi = \frac{49.9}{50.9}$$

Then,

$$\pi = .980$$

$$probability(success) = 98\%$$

The probability of success resulted at 98%, which is the same as the predictive equation utilizing the variable Total Gaps in lieu of the individual gaps. This result would indicate that there was no difference between individual gaps and total gaps. Analyzing the predictive equation is one mechanism to evaluate the impact of each variable; another "strategy is to evaluate odds ratio: The statistically significant

predictors that change the odds of the outcome the most are interpreted as the most significant" (Tabachnick & Fidell, 2007, p. 469). When evaluating odds ratio, the "farther the odds ratio from 1, the more influential the predictor" (p. 469). The magnitude of the odds ratio for each of the level gaps ranged from .75 to .86. This indicated that a student was 1.16 to 1.33 times as likely to fail for each developmental mathematic gap a student has, all other factors being equal. Therefore, it can be concluded that all the gaps had a negative impact on the likelihood of College Algebra Success.

The previous two sections analyzed all 885 students based on Total Gaps and individual gaps Levels 1-4. The results from each analysis were comparable. The subsequent sections analyzed, via a logistic regression, the student data based on their Initial Placement Level. For each Level, two logistic regressions were analyzed by substituting Total Gaps with individual gaps for Levels 1-4.

Analysis on Initial Placement Level 1 - Total Gaps

A direct logistic regression analysis was performed for only those students who were initially placed in the first level of the developmental mathematics course sequence. College algebra success was the outcome, and three predictors were included: total terms enrolled, number of attempts to pass college algebra, and total semester gaps within the mathematics sequence to the successful completion of college algebra. Data from 885 students, first-time enrolled in college during the 2004 fall semester were available for analysis, and 237 were selected as Level 1 students: 38 students successfully completed college algebra, and 199 students did not successfully complete.

A test of the full model for Level 1 students with all three predictors against a constant-only model was statistically significant, χ^2 (3, n = 237) = 116.472, $p < .001$, indicating that the predictors, as a set, reliably distinguished between success and failure in college algebra. Classification by the model as illustrated in Table 10, was average, with 73.7% of successful completion and 97.5% of unsuccessful completions predicted, for an overall success rate for the model of 93.7%, compared to 84.0% without it.

Table 10

Classification Table - Level 1

		Predicted Correct Percentage	
	Observed	Block 0	Block 1
Fail	199	100%	97.5%
Pass	38	0%	73.7%
Overall Percentage		84.0%	93.7%

The Omnibus Tests of Models results were statistically significant, χ^2 (3, n = 237) = 116.472, $p < .001$, which indicated that the model performed better than with no predictors included. The Hosmer and Lemeshow test also supported this, with a significance level greater than .05, χ^2 (8, n = 237) = 13.701, p = .09. The model summary provides an indication of the amount of variation in the dependent variables as explained by the model. In this case the Cox & Snell R Square and the Nagelkerke R Square values, .388 and .663, respectively, indicated the amount of variation. This suggests that between 38.8% and 66.3% of the variability was explained by this set of variables.

Table 11 shows regression coefficients, Wald statistics, odds ratio, and standard errors for each of the predictors. According to the Wald criterion and the odds ratio, the

predictor college algebra attempts had the most effect on predicting college algebra success. In other words, the student's odds of College Algebra Success increased seven fold with each attempt at the course, which appears logical, followed by terms enrolled then total gaps. The variable Total Gaps with a factor of 0.65, indicated it was a negative factor on College Algebra Success. All three predictors contribute significantly to the predictive ability of the model.

Table 11

Summary of Logistic Regression Analysis Predicting College Algebra Success –Initial Placement Level 1

Variable	*B*	*SE*	Odds ratio	Wald statistic
Total gaps	-0.43	0.12	0.65	12.91
College algebra attempts	2.03	0.44	7.60	21.77
Terms enrolled	0.60	0.14	1.82	19.41
Constant	-4.60	0.58	0.02	48.92

$p < .01$

The following predictive equation was derived from the summary of logistic regression for students who were initially placed in Level 1 and student data from a Level 1 student as presented below. The results of this predictive equation provided the probability of success in college algebra for students who were initially placed into Level 1 of the developmental mathematics course sequence.

Student Data

Initial Placement Level = 1

Total Gaps = 8 (L1 Gap = 0) (L2 Gap = 3) (L3 Gap = 3) (L4 Gap = 2)

Total Terms Enrolled = 12

College Algebra Attempts = 1

Where,

$$probability\ (success) = \pi$$

And,

$$\pi = \frac{e^{\alpha + B_1(TotalGaps) + B_2(TermsEnrolled) + B_3(Attempts)}}{1 + e^{\alpha + B_1(TotalGaps) + B_2(TermsEnrolled) + B_3(Attempts)}}$$

$$\pi = \frac{e^{-4.06 + (-.43)(8) + (.60)(12) + (2.03)(1)}}{1 + e^{-4.06 + (-.43)(8) + (.60)(12) + (2.03)(1)}}$$

$$\pi = \frac{5.64}{6.64}$$

Then,

$$\pi = .85$$

$$probability(success) = 85\%$$

The predictive equation using Total Gaps results indicated the probability of success at 85%.

The odds ratio for Total Gaps revealed that the more developmental mathematic gaps a student had, the less likely it was for the student to complete college algebra successfully. For example for each additional gap, the likelihood of failure increased by

1.53 times, all other factors being equal. The impact of total gaps on Level 1 students was similar to that of the model that included all students.

Analysis on Initial Placement Level 1 – Individual Gaps

A direct logistic regression analysis was performed for only those students who were initially placed in the first level of the developmental mathematics course sequence, but substituting the individual level gaps for the variable Total Gaps. College algebra success was the outcome and the predictors included total terms enrolled, number of attempts to pass college algebra, and L1-4 gaps. Data from 885 students, first-time enrolled in college during the 2004 fall semester were available for analysis and 237 were selected as Level 1 students: 38 students successfully completed college algebra, and 199 students did not successfully complete.

A test of the full model for Level 1 students with the predictors against a constant-only model was statistically significant, χ^2 (6, n = 237) = 101.535, $p < .001$, indicating that the predictors, as a set, reliably distinguished between success and failure in college algebra. Classification by the model as illustrated in Table 12, was average, with 63.2% of successful completion and 97.0% of non-successful completions predicted, for an overall success rate for the model of 91.6%, compared to 84.0% without it.

Table 12

Classification Table - Level 1

	Observed	Predicted Correct Percentage Block 0	Block 1
Fail	199	100%	97.0%
Pass	38	0%	63.2%
Overall Percentage		84.0%	91.6%

The Omnibus Tests of Models results were statistically significant, χ^2 (6, n = 237) = 101.535, $p < .001$, which indicated that the model performed better than with no predictors included. The model summary provides an indication of the amount of variation in the dependent variables as explained by the model. In this case, the Cox & Snell R Square and the Nagelkerke R Square values, .348 and .595, respectively, indicate the amount of variation. This suggested that between 34.8% and 59.5% of the variability was explained by this set of predictors.

Table 13 shows regression coefficients, Wald statistics, odds ratio, and standard errors for each of the predictors. According to the Wald criterion and the odds ratio, the predictor college algebra attempts had the most effect on predicting college algebra success, followed by terms enrolled, then individual gaps.

Table 13

Summary of Logistic Regression Analysis Predicting College Algebra Success - Initial Placement Level 1 by Individual Gaps

Variable	*B*	*SE*	Odds ratio	Wald statistic
L1 Gap	-0.18	0.13	0.84	2.02
L2 Gap	-0.11	0.12	0.90	0.87
L3 Gap	-0.20	0.18	0.82	1.29
L4 Gap	0.09	0.12	1.10	0.66
College algebra attempts	1.81	0.46	6.10	15.72
Terms enrolled	0.26	0.08	1.30	11.27
Constant	-4.01	0.54	0.02	55.78

$p < .01$

The following predictive equation was derived from the summary of logistic regression for students who were initially placed in Level 1 and analyzed by individual gaps. The student data from a Level 1 student was presented below. The results of this predictive equation provided the probability of success in college algebra for students who were initially placed into Level 1 of the developmental mathematics course sequence.

Student Data

Initial Placement Level = 1

Total Gaps = 8 (L1 Gap = 0) (L2 Gap = 3) (L3 Gap = 3) (L4 Gap = 2)

Total Terms Enrolled = 12

College Algebra Attempts = 1

Where,

$$probability\ (success) = \pi$$

And,

$$\pi = \frac{e^{\alpha + B_1(L1Gap) + B_2(L2Gap) + B_3(L3Gap) + B_4(L4Gap) + B_5(Attempts) + B_6(TermsEnrolled)}}{1 + e^{\alpha + B_1(L1Gap) + B_2(L2Gap) + B_3(L3Gap) + B_4(L4Gap) + B_5(Attempts) + B_6(TermsEnrolled)}}$$

$$\pi = \frac{e^{-4.01 + (-.15)(0) + (-.11)(3) + (-.2)(3) + (.09)(2) + (1.81)(1) + (.26)(12)}}{1 + e^{-4.01 + (-.15)(0) + (-.11)(3) + (-.2)(3) + (.09)(2) + (1.81)(1) + (.26)(12)}}$$

$$\pi = \frac{1.19}{2.19}$$

Then,

$$\pi = .54$$

$$probability(success) = 54\%$$

The result of Initial Level 1 students by individual gap indicated that for the sample data the probability of success was 54%. In comparison, the predictive equation using Total Gaps resulted in a probability of success of 85%.

In this predictive model, the individual level gaps had a lesser impact on the prediction of College Algebra Success. However, the predictive equation revealed that the L1 Gap had a Wald criterion of 2.02 and an odds ratio of .84. For the students initially placed in Level 1, the L4 Gap with a positive beta coefficient of .09 indicated that the L4 Gap is a positive factor in predicting College Algebra Success. This indication is counter intuitive and may be attributable to the small number of Level 1 students who eventually succeeded at college algebra (*n*=38), which yields a small sample size.

Analysis on Initial Placement Level 2 – Total Gaps

Another direct logistic regression analysis was performed for only those students who were initially placed in the second level of the developmental mathematics course sequence. College algebra success was the outcome, and three predictors were included: total terms enrolled, number of attempts to pass college algebra, and total semester gaps within mathematics sequence to the successful completion of college algebra. Data from 885 students, first-time enrolled in college during the 2004 fall semester were available for analysis, and 238 were selected as Level 2 students: 64 students successfully completed college algebra, and 174 students did not successfully complete.

A test of the full model for Level 2 students with all three predictors against a constant-only model was statistically significant, indicating that the predictors, as a set, reliably distinguished between success and failure in college algebra. Classification by the model as illustrated by Table 14 was above average, with 92.2% of successful completion and 98.9% of unsuccessful completions predicted, for an overall success rate of 97.1% for the model, compared to 73.1% without.

Table 14

Classification Table - Level 2

		Predicted Correct Percentage	
	Observed	Block 0	Block 1
Fail	174	100%	98.9%
Pass	64	0%	92.2%
Overall Percentage		73.1%	97.1%

The Omnibus Tests of Models results were statistically significant, χ^2 (3, n = 238) = 206.562, $p < .001$, which indicated that the model performed better than with no predictors included. The Hosmer and Lemeshow test also supported this with a significance level greater than .05, χ^2 (6, n = 238) = 11.558, $p = .07$. The model summary provides an indication of the amount of variation in the dependent variables as explained by the model. In this case, the Cox & Snell R Square and the Nagelkerke R Square values, .580 and .843, respectively, indicated the amount of variation. This suggested that between 58.0% and 84.3% of the variability was explained by this set of variables.

Table 15 shows regression coefficients, Wald statistics, odds ratio, and standard errors for each of the predictors.

Table 15

Summary of Logistic Regression Analysis Predicting College Algebra Success – Initial Placement Level 2

Variable	*B*	*SE*	Odds ratio	Wald statistic
Total gaps	-0.64	0.14	0.53	21.84
College algebra attempts	2.88	0.52	17.89	30.65
Terms enrolled	0.79	0.16	2.20	25.20
Constant	-4.35	0.70	0.01	38.37

$p < .01$

According to the Wald criterion, the predictor college algebra attempts had the most effect on predicting college algebra success, followed by terms enrolled then total gaps, χ^2(3, n = 238) = 206.562, $p < .001$. All three predictors contributed significantly to the predictive ability of the model. The following predictive equation was derived from the summary of logistic regression for students who were initially placed in Level 2 and

student data from a Level 2 student as presented below. The results of this predictive equation provided the probability of success in college algebra for students who were initially placed into Level 2 of the developmental mathematics course sequence.

Student Data

Initial Placement = 2 (Level 2)

Total Gaps = 5 (Level 3 Gap = 3) + (Level 4 Gap = 2)

Total Terms Enrolled = 10

College Algebra Attempts = 2

Where,

$$probability\ (success) = \pi$$

And,

$$\pi = \frac{e^{\alpha+\beta 1(TotalGaps)+\beta_2(TermsEnrolled)+\beta_3(Attempts)}}{1+e^{\alpha+\beta_1(TotalGaps)+\beta_2(TermsEnrolled)+\beta_3(Attempts)}}$$

$$\pi = \frac{e^{-4.35+(-.64)(5)+(.79)(10)+(2.88)(2)}}{1+e^{-4.35+(-.64)(5)+(.79)(10)+(2.88)(2)}}$$

$$\pi = \frac{450.34}{451.34}$$

Then,

$$\pi = 1.00$$

$$probability(success) = 100\%$$

The results of the predictive equation with the sample student data indicated that the student had a 100% probability of success.

The odds ratio for total gaps of 0.53 indicated that the more developmental mathematics gaps a student had, the less likely it was for the student to successfully

complete college algebra. For example, for each additional gap, the likelihood of failure increased by 1.88 times, all other factors being equal. The impact of total gaps on Level 2 students was greater than that of the original model. In reviewing the odds ratio for the two lowest levels of developmental mathematics courses, the Total Gaps of Level 2 students had a greater impact than the Level 1 and full model, which included all levels.

Analysis on Initial Placement Level 2 - Individual Gaps

Another direct logistic regression analysis was performed for only those students who were initially placed in the second level of the developmental mathematics course sequence, but substituted the individual gaps from Level 2 to 4 instead of the variable Total Gaps. College algebra success was the outcome, and predictors included: total terms enrolled, number of attempts to pass college algebra, and L2-4 Gaps. Data from 885 students, first-time enrolled in college during the 2004 fall semester were available for analysis, and 238 were selected as Level 2 students: 64 students successfully completed college algebra, and 174 students did not successfully complete.

A test of the full model for Level 2 students with all three predictors against a constant-only model was statistically significant, indicating that the predictors, as a set, reliably distinguished between success and failure in college algebra. Classification by the model as illustrated by Table 16 was above average, with 92.2% of successful completion and 98.9% of unsuccessful completions predicted, for an overall success rate of 97.1% for the model, compared to 73.1% without.

Table 16

Classification Table - Level 2

	Observed	Predicted Correct Percentage Block 0	Block 1
Fail	174	100%	93.1%
Pass	64	0%	89.1%
Overall Percentage		73.1%	92.0%

The Omnibus Tests of Models results were statistically significant, χ^2 (5, n = 238) = 176.487, $p < .001$, which indicated that the model performed better than with no predictors included. The model summary provides an indication of the amount of variation in the dependent variables as explained by the model. In this case, the Cox & Snell R Square and the Nagelkerke R Square values, .524 and .761, respectively, indicated the amount of variation. This suggested that between 52.4% and 76.1% of the variability was explained by this set of predictors.

Table 17 shows regression coefficients, Wald statistics, odds ratio, and standard errors for each of the predictors. According to the Wald criterion, the predictor college algebra attempts had the most effect on predicting college algebra success, followed by terms enrolled then the L2 Gap, L4 Gap, and L3 Gap. All predictors contributed significantly to the predictive ability of the model.

Table 17

Summary of Logistic Regression Analysis Predicting College Algebra Success

Variable	*B*	*SE*	Odds ratio	Wald statistic
L2 Gap	-0.36	0.12	0.70	9.78
L3 Gap	-0.13	0.10	0.88	1.62
L4 Gap	-0.29	0.11	0.75	7.22
College algebra attempts	3.63	0.57	37.53	40.36
Terms enrolled	0.36	0.08	1.43	20.29
Constant	-4.68	0.70	0.01	45.15

$p < .01$

The following predictive equation was derived from the summary of logistic regression for students who were initially placed in Level 2 by individual gaps and student data from a Level 2 student as presented below. The results of this predictive equation provided the probability of success in college algebra for students who were initially placed into Level 2 of the developmental mathematics course sequence.

Student Data

Initial Placement = 2 (Level 2)

Total Gaps = 5 (Level 3 Gap = 3) + (Level 4 Gap = 2)

Total Terms Enrolled = 10

College Algebra Attempts = 2

Where,

$$probability\ (success) = \pi$$

And,

$$\pi = \frac{e^{\alpha + \beta_1 (L\,2Gaps) + \beta_2 (L\,3Gaps) + \beta_3 (L\,4\,Gaps + \beta_5 (TermsEnrolled) + \beta\,6 (Attempts)}}{1 + e^{\alpha + \beta_1 (L\,2Gaps) + \beta_2 (L\,3Gaps) + \beta_3 (L\,4\,Gaps) + \beta_4 (TermsEnrolled) + \beta_5 (Attempts)}}$$

$$\pi = \frac{e^{(-4.68)+(-.36)(0)+(-.13)(3)+(-.29)(2)+3.63)(2)+(.36)(10)}}{1+e^{(-4.68)+(-.36)(0)+(-.13)(3)+(-.29)(2)+3.63)(2)+(.36)(10)}}$$

$$\pi = \frac{183.09}{184.09}$$

Then,

$$\pi = .99$$

$$probability(success) = 99\%$$

The results of the predictive equation based on individual gaps indicated a 99% probability of success, which was in agreement with the results of the predictive equation based on Total Gaps at 100%.

The odds ratio for total gaps of 0.53 indicates that the more developmental mathematic gaps a student had, the less likely it was for the student to successfully complete college algebra. For example, for each additional gap, the likelihood of failure increased by 1.88 times, all other factors being equal. The impact of total gaps on Level 2 students was greater than that of the original model. In reviewing the odds ratio for the two lowest levels of developmental mathematics courses, the Total Gaps of Level 2 students had a greater impact than the Level 1 and full model, which included all levels.

Analysis on Initial Placement Level 3 – Total Gaps

A fourth direct logistic regression analysis was performed for only those students who were initially placed in the third level of the developmental mathematics course sequence. College algebra success was the outcome and three predictors included: total terms enrolled, and number of attempts to pass college algebra, and total semester gaps within mathematics sequence to the successful completion of college algebra. Data from 885 students, first-time enrolled in college during the 2004 fall semester were available for analysis, and 152 were selected as Level 3 students: 62 students successfully completed college algebra, and 90 students did not successfully complete.

A test of the full model for Level 3 students with all three predictors against a constant-only model was statistically significant, χ^2 (3, n = 152) = 98.334, $p < .001$, indicating that the predictors, as a set, reliably distinguished between success and failure in college algebra. Classification by the model as illustrated in Table 18 was average, with 88.2% of successful completion and 82.3% of unsuccessful completions predicted, for an overall success rate of 92.2% for the model, compared to 59.2% without.

Table 18

Classification Table - Level 3

		Predicted Correct Percentage	
	Observed	Block 0	Block 1
Fail	90	100%	92.2%
Pass	62	0%	82.3%
Overall Percentage		59.2%	88.2%

The Omnibus Tests of Models results were statistically significant, χ^2 (3, n = 152) = 98.334, $p < .001$, which indicated that the model performed better than with no predictors included. The Hosmer and Lemeshow test also supported this, with a significance level greater than .05, χ^2 (7, n = 152) = 11.115, $p = .134$. The model summary provides an indication of the amount of variation in the dependent variables as explained by the model. In this case, the Cox & Snell R Square and the Nagelkerke R Square values, .476 and .643, respectively, indicated the amount of variation. This suggested that between 47.6% and 64.3% of the variability was explained by this set of predictors.

Table 19 shows regression coefficients, Wald statistics, odds ratio, and standard errors for each of the predictors.

Table 19

Summary of Logistic Regression Analysis Predicting College Algebra Success – Initial Placement Level 3

Variable	*B*	*SE*	Odds ratio	Wald statistic
Total gaps	-0.32	0.07	0.73	19.12
College algebra attempts	1.27	0.30	3.56	18.13
Terms enrolled	0.63	0.12	1.88	26.33
Constant	-3.51	0.61	0.03	33.54

$p < .01$

According to the Wald criterion, the predictor college algebra attempts had the most effect on predicting Terms Enrolled, followed by Total Gaps, then College Algebra

Attempts, $\chi^2(3, n = 152) = 98.334, p < .001$. All three predictors contributed significantly to the predictive ability of the model.

The following predictive equation was derived from the summary of logistic regression for students who were initially placed in Level 3 and student data from a Level 3 student as presented below. The results of this predictive equation provided the probability of success in college algebra for students who were initially placed into Level 3 of the developmental mathematics course sequence.

Student Data

Initial Placement = 3 (Level 3)

Total Gaps = 3 (Level 3 Gap = 1) + (Level 4 Gap = 2)

Total Terms Enrolled = 5

College Algebra Attempts = 1

Where,

$$probability\ (success) = \pi$$

And,

$$\pi = \frac{e^{\alpha + \beta 1(TotalGaps) + \beta_2(TermsEnrolled) + \beta_3(Attempts)}}{1 + e^{\alpha + \beta_1(TotalGaps) + \beta_2(TermsEnrolled) + \beta_3(Attempts)}}$$

$$\pi = \frac{e^{-3.51 + (-.32)(3) + (.63)(5) + (1.27)(1)}}{1 + e^{-3.51 + (-.32)(3) + (.63)(5) + (1.27)(1)}}$$

$$\pi = \frac{1.05}{2.05}$$

Then,

$$\pi = .51$$

$$probability(success) = 51\%$$

The results of the predictive equation with the sample student data indicated that the student had a 51% probability of success.

The odds ratio for total gaps of 0.73 indicated that the more developmental mathematic gaps a student had, the less likely it was for the student to successfully complete college algebra. For example, for each additional gap, the likelihood of failure increased by 1.37 times, all other factors being equal. Based on a comparison of the respective odds ratios, the impact of Total Gaps on Level 3 students was less than the full model and the two lowest levels of Initial Placement.

Analysis on Initial Placement Level 3 by Individual Gaps

A direct logistic regression analysis was performed for only those students who were initially placed in the third level of the developmental mathematics course sequence, but substituted individual Level 3 and 4 gaps for the variable Total Gaps. College algebra success was the outcome and the predictors included total terms enrolled, number of attempts to pass college algebra, L3 Gaps and L4 Gaps. Data from 885 students, first-time enrolled in college during the 2004 fall semester were available for analysis, and 152 were selected as Level 3 students: 62 students successfully completed college algebra, and 90 students did not successfully complete.

A test of the full model for Level 3 students with all three predictors against a constant-only model was statistically significant, χ^2 (4, n = 152) = 77.023, $p < .001$, indicating that the predictors, as a set, reliably distinguished between success and failure in college algebra. Classification by the model as illustrated in Table 20 was average, with 74.2% of successful completion and 86.7% of unsuccessful completions predicted, for an overall success rate of 81.6% for the model, compared to 59.2% without.

Table 20

Classification Table - Level 3

	Observed	Predicted Correct Percentage Block 0	Block 1
Fail	90	100%	86.7%
Pass	62	0%	74.2%
Overall Percentage		59.2%	81.6%

The Omnibus Tests of Models results were statistically significant, χ^2 (4, n = 152) = 77.023, $p < .001$, which indicated that the model performed better than with no predictors included. The model summary provides an indication of the amount of variation in the dependent variables as explained by the model. In this case, the Cox & Snell R Square and the Nagelkerke R Square values, .398 and .536, respectively, indicated the amount of variation. This suggested that between 39.8% and 53.6% of the variability was explained by this set of predictors.

Table 21 shows regression coefficients, Wald statistics, odds ratio, and standard errors for each of the predictors. According to the Wald criterion, the predictor Terms Enrolled had the most effect on predicting college algebra success, followed by College Algebra Attempts then L3 Gap and L4 Gap. All the predictors contributed significantly to the predictive ability of the model.

Table 21

Summary of Logistic Regression Analysis Predicting College Algebra Success-Initial Level 3

Variable	*B*	*SE*	Odds ratio	Wald statistic
L3 Gap	-0.16	0.07	0.85	6.14
L4 Gap	-0.13	0.07	0.88	3.92
College algebra attempts	1.33	0.34	3.78	15.52
Terms enrolled	0.45	0.98	1.57	21.16
Constant	-3.59	0.59	0.03	36.85

$p < .01$

The following predictive equation was derived from the summary of logistic regression for students who were initially placed in Level 3 and student data from a Level 3 student as presented below. The results of this predictive equation provided the probability of success in college algebra for students who were initially placed into Level 3 of the developmental mathematics course sequence.

Student Data

Initial Placement = 3 (Level 3)

Total Gaps = 3 (Level 3 Gap = 1) + (Level 4 Gap = 2)

Total Terms Enrolled = 5

College Algebra Attempts = 1

Where,

$$probability\ (success) = \pi$$

And,

$$\pi = \frac{e^{\alpha+\beta_1(L3Gaps)+\beta_2(L4Gaps)+\beta_3(TermsEnrolled)+\beta_4(Attempts)}}{1+e^{\alpha+\beta_1(L3Gaps)+\beta_2(L4Gaps)+\beta_3(TermsEnrolled)+\beta_4(Attempts)}}$$

$$\pi = \frac{e^{-3.59+(-.16)(1)+(-.13)(2)+(.45)(5)+(1.33)(1)}}{1+e^{-3.59+(-.16)(1)+(-.13)(2)+(.45)(5)+(1.33)(1)}}$$

$$\pi = \frac{1.54}{2.54}$$

Then,

$$\pi = .61$$

$$probability(success) = 61\%$$

The results of the predictive equation based on individual gaps indicated a 61% probability of success, which was similar to the results of the predictive equation based on Total Gaps at 51%.

The odds ratio for L3 and L4 gaps indicated that individually the gaps represented a small portion of the total gaps of 0.73, which indicated that the more developmental mathematic gaps a student had, the less likely it was for the student to complete college algebra successfully. For example for each additional gap, the likelihood of failure increased by a 1.37 times, all other factors being equal. Based on a comparison of the respective odds ratios, the impact of Total Gaps on Level 3 students was less than the full model and the two lowest levels of Initial Placement.

Analysis on Initial Placement Level 4 – Total Gaps/Individual Gaps

The analysis for students initially placed in Level 4 required a single logistic regression since Total Gaps and L4 Gaps were the same value. These students only had Level 4 Gaps. A direct logistic regression analysis was performed for only those students

who were initially placed in Level 4, college ready, based on college algebra success as the outcome and three predictors: total terms enrolled, number of attempts to pass college algebra, and total semester gaps within mathematics sequence to the successful completion of college algebra. Data from 885 students, first-time enrolled in college during the 2004 fall semester were available for analysis, and 258 were selected as level 4 students: 199 students successfully completed college algebra, and 59 students did not successfully complete.

A test of the full model for Level 4 students with all three predictors against a constant-only model was statistically significant, χ^2 (3, n = 258) = 108.036, $p < .001$, indicating that the predictors, as a set, reliably distinguished between success and failure in college algebra. Classification by the model as illustrated in Table 22 was average, with 93.5% of successful completion and 67.8% of non-successful completions predicted, for an overall success rate of 87.6% for the model, compared to 77.1% without.

Table 22

Classification Table - Level 4

		Predicted Correct Percentage	
	Observed	Block 0	Block 1
Fail	59	0%	67.8%
Pass	199	100%	93.5%
Overall Percentage		77.1%	87.6%

The Omnibus Tests of Models results were statistically significant, χ^2 (3, n = 258) = 108.036, $p < .001$, which indicated that the model performed better than with no predictors included. The Hosmer and Lemeshow test also supported this, with a

significance level greater than .05, χ^2 (8, n = 258) = 6.955, p = .542. The model summary provides an indication of the amount of variation in the dependent variables as explained by the model. In this case, the Cox & Snell R Square and the Nagelkerke R Square values, .342 and .519, respectively, indicated the amount of variation. This suggested that between 34.2% and 51.9% of the variability was explained by this set of variables.

Table 23 shows regression coefficients, Wald statistics, odds ratio, and standard errors for each of the four predictors. According to the Wald criterion, the predictor terms enrolled had the most effect on predicting college algebra success, followed by total gaps, then college algebra attempts. All predictors contributed significantly to the predictive ability of the model.

Table 23

Summary of Logistic Regression Analysis Predicting College Algebra Success – Initial Placement Level 4

Variable	*B*	*SE*	Odds ratio	Wald statistic
Total gaps	-0.49	0.08	0.61	35.88
College algebra attempts	0.30	0.36	1.34	0.66
Terms enrolled	0.80	0.12	2.22	42.73
Constants	-1.32	0.56	0.27	5.51

$p < .01$

The following predictive equation was derived from the summary of logistic regression for students who were initially placed in Level 4 and student data from a Level 4 student as presented below. The results of this predictive equation provided the

probability of success in college algebra for students who were initially placed into Level 4 of the developmental mathematics course sequence.

Student Data

Initial Placement = 4 (Level 4)

Total Gaps = 0 (Level 4 Gap = 0)

Total Terms Enrolled = 2

College Algebra Attempts = 2

Where,

$$probability\ (success) = \pi$$

And,

$$\pi = \frac{e^{\alpha+\beta 1(TotalGaps)+\beta_2(TermsEnrolled)+\beta_3(Attempts)}}{1+e^{\alpha+\beta_1(TotalGaps)+\beta_2(TermsEnrolled)+\beta_3(Attempts)}}$$

$$\pi = \frac{e^{-1.32+(-.49)(0)+(.80)(2)+(.30)(2)}}{1+e^{-1.32+(-.49)(0)+(.80)(2)+(.30)(2)}}$$

$$\pi = \frac{2.41}{3.41}$$

Then,

$$\pi = .71$$

$$probability(success) = 71\%$$

The results of the predictive equation with the sample student data indicated that the student had a 51% probability of success.

The odds ratio for total gaps of 0.61 indicated that the more gaps a student had, the less likely it was for the student to successfully complete college algebra. For example, for each additional gap, the likelihood of failures increased by 1.64 times, all

other factors being equal. The impact of total gaps on Level 4 students was similar to that of the original model with all levels included.

Summary of Logistic Regression Analysis

These results confirmed that Total Gaps in the developmental mathematics course sequence had a statistically significant negative impact on successful completion of College Algebra. The results showed that the greatest impact was on Level 2 students, with an increase in the likelihood of failure of 1.89 times. Based on the additional analysis, the individual gaps at each level had a diminished impact on College Algebra Success.

Table 24

Summary of Logistic Regressions

Placement Level	Description	Gap 1	Gap 2	Gap 3	Gap 4	Total Gaps
Level 1	Odds Ratio	0.84	0.90	0.82	1.10	0.65
	Odd to Fail	1.19	1.11	1.22	0.91	1.54
Level 2	Odds Ratio		0.70	0.88	0.75	0.53
	Odd to Fail		1.43	1.14	1.33	1.89
Level 3	Odds Ratio			0.85	0.88	0.73
	Odd to Fail			1.18	1.14	1.37
Level 4	Odds Ratio				0.63	0.63
	Odd to Fail				1.59	1.59
Levels 1-4	Odds Ratio	0.81	0.75	0.84	0.86	0.61
	Odd to Fail	1.23	1.33	1.19	1.16	1.64

Building upon the odds ratio information, another analysis was performed to determine if there were any correlations between enrollment in the first semester (2004

fall) and College Algebra Success. This analysis found that for this cohort, the enrollment in the first semester was not statistically significant, with a correlation of .048 at $p = .151$.

Summary of Research Question Results

Based on the literature, the researcher developed two research questions:

1 What is the relationship between the number of semester gaps within the developmental mathematics course sequence and successful completion of college algebra?

The variable Total Gaps was statistically significant in predicting college algebra success. It was negatively correlated at 0.30, $p < .01$ and had an odds ratio of 0.61. These measures indicated that each semester gap increased the likelihood of failure in the course of college algebra by 1.64 times. Additional analysis on the gaps at each level was also found to be statistically significant; however, the impact was not as great as Total Gaps. Further analysis conducted for each individual gap revealed that the Level 1-3 gaps were predictors of College Algebra Success; however, the impact of these gaps was less than the predictor Total Gaps. The results of the logistic regression analyzed by Initial Placement Level as well as individual gaps at levels 1-4 also indicated that semester gaps had a negative impact on college algebra success.

2 Do the gaps before enrollment in college algebra predict difficulty in the successful completion of college algebra?

The correlation of the gap between the last developmental course and college algebra to College Algebra Success was found not to be statistically significant.

Upon further analysis for Level 1 students, the Level 4 Gap had a positive impact on college algebra success. This may have been a result of having a small number of cases from Level 1 who successfully completed college algebra (n = 38). For Level 2 students, the Level 4 Gap had a negative effect on College Algebra Success, increasing the likelihood of failure by 1.33 times; however, the impact was less than Total Gaps. For Level 3 students, the Level 4 Gap had a negative effect on College Algebra Success by increasing the likelihood of failure by 1.13 times. For Level 4 students, the Level 4 Gap had a negative effect on College Algebra Success by increasing the likelihood of failure by 1.20 times. For all students, the analysis revealed that the Level 4 Gap also had a negative impact on College Algebra Success by increasing the likelihood of failure by 1.17 times. Thus, even though the Level 4 Gap was not statistically correlated to College Algebra Success through a correlation analysis, the Level 4 Gap was statistically significant as predictor in the logistic regressions.

Chapter 5

This study was designed to follow the first-time-in-college (FTIC) students' enrollment in developmental mathematics courses beginning with the fall 2004 semester through the second summer semester of 2010, a period of six years.

The completion of college algebra represents an important milestone on a student's journey toward graduation. For the Community College, mathematics, specifically college algebra, signifies a significant roadblock for students. Seventy-one percent of the first time in college students in the fall 2004 required some level of remediation. The progression of these students through the developmental mathematics course sequence is dismal for most. The Level 4 or college ready students perform better, 77% successfully completing college algebra; however, for each level below Level 4, the success rate decreased by over half.

This study showed that, while not the only predictor of college algebra success, a statistically significant factor in the failure to complete college algebra successfully is the number of semester gaps within the developmental mathematics course sequence. The implications of the gaps were evident in the course progression data, which revealed that a large percentage of students failed to progress to the next course in the sequence even after completing the prior level. Many of these students failed to complete only because they failed to enroll in the subsequent course. The semester gaps that have the largest impact based on the odds ratios are those for Level 2 students. The Level 2 Gap in the logistic regression for all students also had the largest of the individual odds ratio, .754, which indicated that each additional Level 2 Gap increased the likelihood of failure by 1.33 times. It appears that gaps at this low level in developmental mathematics course

sequence have a negative impact on success in college algebra, more so than the other levels. It is important to note that Level 1 students are deficient not only in algebra but also fundamental arithmetic. The Level 2 are placed with some level of introductory algebra skills.

The results of this study provide evidence that supports community colleges' use of various strategies that minimize the occurrence of gaps within the developmental course sequence. One strategy is to eliminate the opportunities for gaps in the course sequence. For example, community colleges could require students to maintain enrollment in the course sequence.

Another strategy involves prescriptive advising, especially with regards to the developmental mathematics course sequence. College advisors should be more prescriptive in ensuring that students remain on track and discourage semester gaps within the course sequence. In addition, community colleges must remove the opportunities for students to self select semester gaps. The occurrence of this self-service registration is more evident as colleges continue to push toward more online and automated registration processes. Thus, in the move toward online registrations, safeguards must be in place to ensure that developmental students stay on track with their developmental course sequence.

Comparison to Literature Review

As noted in the literature review, Bailey (2009) found that two-thirds or more of community college students enter college with weak academic skills. The results of this study supported the higher estimates with 71% of the students entering in the 2004 fall semester assessed as below college ready. Another result that agreed with Bailey was

that less than one-third of those students referred to the developmental course sequence complete it. Twenty-six percent completed the sequence in the current study.

The literature review identified that difficulties in the completion of the developmental mathematic course sequence is a documented phenomenon. Bailey, Jeong, and Cho (2008) found that only a few students complete their developmental course sequence. The results of this study's course progression data support Bailey and Cho's finding that a small percentage of students complete the full developmental course sequence.

This phenomenon also supports Levin and Calcagno's (2007) finding that there is a place for linked or paired courses within the developmental mathematics course sequence. Bailey and Cho (2010) also found that linked courses, which included the highest level of remediation, and a college-level course accelerate the learning process. The analysis in this study revealed that the gap for Level 2 students had the largest impact on success in college algebra, based on the odds ratio comparison. This finding may support both Levin and Calcagno's (2007) and Bailey and Cho's (2010) statement that linked courses, especially with the college level "gatekeeper" course, accelerate student learning and have a positive impact on student success. Although this study did not address linked courses directly, the study supports strategies that eliminate gaps between developmental mathematics courses.

This study supports Scott-Clayton's (2011) argument that community college students need more structure and less opportunity to deviate. The results from the course progression data and the gap analysis support that by adding structure, institutions can

remove gaps from the predictors impeding college algebra success. The results could improve student success.

From a theoretical perspective, Grippin and Peters (1984) argued that if a skill was not used, it would be expected to be lost, but only if it was not mastered or "stamped-in." The results of the gap analysis support this argument. This study has found that the more gaps a student has within the developmental mathematics course sequence the less chance of success the student has at successfully completing college algebra. The gaps in the developmental mathematics course sequence have a statistically significant negative impact on college algebra success. The course sequence is a mechanism designed to bring up the student's skills to a level of mastery denoted by successful completion of college algebra. Then, as Grippin and Peters argue, the time lapse or gaps within the sequence have a detrimental impact on college algebra success, because those skills have not been mastered or "stamped-in" at those levels. Thus, the students with gaps fail to keep the algebraic concepts in their working memory and end up either failing to complete college algebra, or complete it after multiple course attempts.

Perhaps a better way to frame the impact of the gaps would be to use a behavioral learning metaphor. For example, let's reexamine the process of how we learn to ride a bicycle and equate the skills acquired during the training wheel portion of learning the skill to the developmental portion of the sequence. A gap or time lapse during this fundamental stage of learning to ride a bicycle has detrimental effects, especially if you attempt to ride the next time without the training wheels, even more so after a three or six month hiatus, the equivalent of one and two semester gaps. The rider will find it difficult because the skills acquired at this early stage have not reached the level of

mastery, and the rider is inexperienced with the different sensations or environmental situations involved with maintaining one's balance without falling. The bicycle metaphor provides a behavioral learning perspective for success in college algebra. The developmental portion of the sequence equates to learning to ride a bicycle with training wheels. Similarly, a student cannot be expected to succeed in college algebra right where he or she left off in his or her developmental course after an absence of rehearsal (gap) and "ride" without falling. Thus, the metaphor provides a visual representation of the gaps within the course sequence. This transfer of skill-based theories to learning algebra supports the hypothesis that gaps within the developmental mathematics course sequence contribute to the decay of the previously acquired concepts that are detrimental to the successful completion of college algebra because these gaps occur before algebraic concepts are mastered.

Success Measures

In the area of measuring student success, the traditional metric to measure success is the graduation rate. However, the success metrics offered in this study support the various roles that community colleges fill within their communities and correspond to identified student goals. In spite of the transformation of community colleges, their original roles which include preparing students for universities, educating the students in the technical fields, as well as preparing students to enter the workforce, are all still relevant. Quigley and Bailey (2003) identified various roles that community colleges are charged to accomplish. These roles include: to be adaptable to educational needs of their community, prepare students to enter the workforce, and provide a solid foundation in the general education. Thus, in order to measure how these institutions are performing with

regards to their roles, success measures must expand beyond graduation rates to include certificate completion and transfers. Community colleges need to do a better job of identifying the student's goals and designing metrics to measure their success accurately. If we expand this notion of success from graduation rates to include certificate completion and transfer, we begin to visualize a different picture of success at community colleges.

For example, one milestone toward graduation is the successful completion of college algebra, and for many students the journey to college algebra requires progression through the developmental mathematics course sequence. Table 25 identifies the number of students by their initial developmental mathematics placement and tracks their progression through each level until reaching Level 4, college algebra.

Table 25

Development Mathematics Progression Through Course Sequence by Initial Placement

		Successfully Completed			
	N	Level 1	Level 2	Level 3	Level 4
Level 1	237	150 (63.3%)	74 (31.2%)	59 (24.9%)	38 (16.0%)
Level 2	238		133 (55.9%)	78 (32.8%)	64 (26.9%)
Level 3	152			92 (60.5%)	62 (40.8%)
Level 4	258				199 (77.1%)
Total	885	150	207	229	363

Note. Level 1 - Basic mathematics; Level 2 - Elementary algebra; Level 3 - Intermediate algebra; Level 4 - College algebra

As evident in the table above, of the 237 students who were initially placed in Level 1, only 16% (38) successfully completed college algebra. The success rate marginally improves for the students placed in Level 2 to only 27% (64 students). It is not until we look at the students assessed as college ready (Level 4) that we see a higher rate of successful completion of college algebra of 77%. However, for all the students placed in developmental mathematics (627), only 26%, or 164 students successfully completed college algebra. Another interesting observation noticeable from the table is the large number of students who failed to progress to the next level in the sequence.

While the 16% successful completion of the Level 1 group appears dismal, upon further inspection there does exist a ray of hope. Table 26 illustrates that of the 237 students who were originally placed in Level 1, 38 students successfully completed college algebra, 22 went on to graduate with a two-year degree and 87 had accomplished one of the success measures of graduation, transfer or certificate completion.

Table 26

Student Success by Initial Placement Level

	N	Graduated AA/AAS	Transfer	Certificate	Combined Success
Level 1	237	22 (9%)	57 (24%)	8 (3%)	87 (37%)
Level 2	238	26 (11%)	49 (21%)	5 (2%)	80 (34%)
Level 3	152	25 (16%)	54 (36%)	1 (1%)	80 (53%)
Level 4	258	60 (23%)	147 (57%)	2 (1%)	209 (81%)
Total	885	133 (15%)	307 (35%)	16 (2%)	456 (52%)

Note: Percentages are calculated based on the number of students per each level. The percentages on the total row are calculated as a percentage of the total.

This expanded version of success aligns more accurately with the roles of community colleges. For example, the results of this study indicated that even though only 15% of the students in the cohort graduated within the six-years of the study, another 35% transferred to four-year institutions. Therefore, the graduation rate of 15% taken in isolation does not accurately represent a complete picture of student success. The 35% of the 885 students who began in 2004 fall represents a significant portion of students whom the community college successfully served. Although this study did not measure student intent, perhaps these students had no intentions of ever graduating from the community college, but full intentions to continue directly toward their bachelor's degree. Thus, when the graduation rate of 15%, transfer rate of 35%, and certificate completion rate of 2% are combined, the result is a combined success rate of 52%. These results support the argument for the need to expand success measures from just graduation to include transfers and certificate completion in order to ascertain a better metric of student success at community colleges.

Future Research

This study focused on the impact of semester gaps on the successful completion of college algebra. However, no attempt was made to distinguish among the various factors that cause students to stop out of the course sequence or fail to complete college algebra. While gaps within the developmental course sequence have been shown to be a factor, further research across learning theories, including behaviorist, cognitivist, and constructivist, is needed. In addition, further research is needed to expand the investigation of the gaps' impact to a larger population in order to determine if the impact found in one cohort exists on a greater scale across various community colleges.

From this study there are additional areas that warrant future research which include factors that were found not to be statistically significant in this study, but may have implications to a wider population. For example, even though no statistical correlation between enrollment in the first term and College Algebra Success was found, if correlations exist on a wider population, the implications could have a tremendous impact on student advising.

Future research in the form of focus groups or surveys administered to students who fail to maintain continuous enrollment within the developmental course sequence may identify the motivational reasons they fail to enroll. Jenkins, Jaggar, and Roska (2010) suggested that "surveying students to understand why they are not enrolling in these courses would help to illuminate factors deterring students from gatekeepers courses and inform the development of policies to motivate and facilitate enrollment in gatekeeper courses" (p. 14).

In the area of measuring success, this study provides compelling evidence that it should be expanded beyond graduation to other areas such as transfer rates and certificate completion. Further research should include an analysis to determine how well community college outcomes are aligned with business needs. Perhaps, in providing documented evidence in the form of cause and effects linking community college outcomes with those skill sets needed by employers, they will see added value in colleges. Demonstrating how these skills acquired in college translate into better employees, which translate into more profits, might provide enough incentive for businesses to be more invested in community colleges and the students.

Another area of future research includes the identification of the factors that contribute to such a high number of high school graduates arriving at college with weak academic skills, especially in the area of mathematics. Although not a new finding, Adelman (2006) documented the correlation between mathematics success in high school and graduation in college; however, there is still a large gap as evidenced by the volume of students arriving on community college campuses without the requisite skills for college-level courses.

Conclusion

Thus, the results of this study provide evidence that semester gaps within the developmental course sequence have a negative impact on success in college algebra. These findings provide administrators with compelling reasons to change institutional policies, provide alternative course formats, and pay closer attention to the enrollment patterns of developmental students. Although the scope of this study was limited to a single community college, the findings and framework should provide a basis for future researchers to replicate the study to different institutions or across multiple institutions.

Finally, the data from the gap analysis supports an investigation of new strategies that may include the utilization of linked courses to achieve gains in student success. This study found that a magic bullet to fix the developmental mathematics problems does not exist. Both researchers and practitioners must dissect the various factors that each independently hinder student success, and develop strategies to over-come them, one such factor is eliminating the semester gaps between the developmental courses and college algebra.

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