

**Programmatic Practices that Promote Student Success in Community College Math
Developmental Education: A Mixed Methods Study**

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A dissertation submitted in partial fulfillment of the requirements for the degree of
Doctor of Philosophy

University of Washington

2015

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Program Authorized to Offer Degree:
Educational Leadership and Policy Studies

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Abstract

Programmatic Practices that Promote Student Success in Community College Math Developmental Education: A Mixed Methods Study¹

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Almost half of all college students in the U.S. attend community colleges; almost sixty percent of these students are referred to remedial English, reading or math through means of a standardized placement exam, with math being a the greatest area of need. While these courses, often as many as four in a sequence, are meant to be a boost for students unprepared for college-level coursework, they have low success rates and few students make it through the entire sequence to succeed in a first college-level math course, leaving them far short of graduation or a meaningful credential.

While developmental (aka remedial) education, i.e. those courses or sequences of courses below the college-level, has received a lot of attention recently due to its high overall costs and low student success rates, current research has largely failed to document, examine, or classify programmatic approaches to developmental education. This lack of information that would facilitate analysis is due in part to the relatively recent recognition of the problem of remediation's ineffectiveness, but it is also because of the difficulty in accessing reliable

¹ The author gratefully acknowledge the support of the Institute of Education Sciences, #R305B090012, in funding this research. I am thankful to all the participants in my case studies, and to my fellow graduate students and scholars across the country who have informed this work. I could not have accomplished this research without the dedicated support of my dissertation chair, William Zumeta, and also to my committee members: Robert Abbott, Michael Knapp, Marge Plecki, Gunnar Almgren, and Debra Bragg.

information about large numbers of programs and the range of definitions, student populations, and perceived quickly shifting innovations (some may go as far as to say educational fads) that developmental education programs encompass. Unfortunately, this lack of a comprehensive picture of developmental education programs has led to either the complete elimination of the programs as unnecessary and perhaps counterproductive for students, or to a focus on a number of disparate approaches with little underlying theory behind them or even agreement as to the problem.

This research is centered on 28 Washington state community colleges and employs a mixed methods approach to answer three main questions:

- 1) To what extent and in what ways do math developmental program elements vary across institutions? Developmental education may vary widely even within one relatively homogenous state system of community colleges, such as the system in Washington. Programs have differing resources devoted to them, as well as differing pedagogy, intervention strategies and approaches, student referral and advancement policies, etc., and this variation has not even been fully described, much less assessed, in previous research.
- 2) To what extent do student outcomes, as measured by completion of the developmental sequence, completion of a first college-level math course, and highest education reached, vary across the different math developmental education programs, after controlling for student characteristics, among the 28 community colleges in Washington State? What proportion of overall variance is contributed by student characteristics vs. programmatic factors? Wide institutional variation has been found in previous outcomes studies of professional-technical programs leading to terminal associate degrees in Washington, suggesting that institutional or

programmatic variables may be contributing significantly to student success or lack of it (Scott-Clayton & Weiss, 2011).

3) What program policies and practices seem to be associated with positive outcomes for developmental education students? Can developmental education programs be categorized in some meaningful way? Is there a “typology” or categorization of programs that identifies characteristics that seem to be associated with either positive or negative results? For example, do schools with better (or worse) results, net of student characteristics, share identifiable programmatic characteristics in terms of policy and practice variables that are positively or negatively associated with student outcomes?

I find from this research that strategies such as reducing the total number of courses in developmental education pathways, implementing via [more appropriate?] standardized tests alternatives to placement in developmental math, and better preparing students for placement assessments, are associated with greater student success in completing the developmental math sequence and in completing a first college level course. I also find that colleges with these more innovative features are significantly more successful than their more traditional institutional peers in terms of student outcomes. However, I also find no variation between colleges in the outcome of highest education level reached, after controlling for student background characteristics. It seems that, at least for this sample followed for three years, college attended did not have a significant association with ultimate educational attainment.

Diving deeper to examine qualitatively selected colleges’ policies, practices, and the perspectives of students, faculty, and administrators, I find wide variation across colleges in pathways, program structure, assessment policies, connection to advising, tutoring, and institutional research departments, and day-to-day concerns and operations. One commonality is

the conviction that teaching that addresses student motivation and confidence in their ability to learn math and piques their interest, factors not usually examined systematically in higher education policy research, is central to developmental education student success.

This research informs strategies for increasing college completion for underprepared students. College completion has emerged as of paramount importance in fostering U.S. economic development and global competitiveness, yet if half of college students are unprepared for college work and thus are unlikely to persist to degree completion despite their motivation to attend college, serious attention should be paid to what can be done to increase their odds of success.

ACKNOWLEDGEMENT

The writing of this dissertation has been the most significant academic challenge I have ever had to face. Without the support, patience and guidance of the following people, this study would not have been completed. It is to them that I owe my deepest gratitude.

Hades Meza, my husband, without whom this dissertation would not have happened. Thank you for your patience, support, and sacrifice while I accomplished my goal. And to my boys, Santiago and Rafael who make me so proud every day.

Professor William Zumeta who undertook to act as my advisor despite his many other academic and professional commitments. Your wisdom, knowledge and commitment to the highest standards inspired and motivated me.

Professor Mike Knapp and Professor Robert Abbott, who, along with Dr. Zumeta dedicated much time and effort to the CREST program. Without the financial, emotional, and academic support offered there I would likely be a part-time graduate student struggling to pay tuition and complete a PhD within ten years. The fact that you are reading this today is because of your efforts.

All the faculty staff and students who so openly spoke with me about their experiences with developmental math. You are truly an inspiration.

My colleagues in CREST and in the community college system. Especially Angie Windus, Chase, Tricia, Robin and Andrea and Doug Emory and Alberto Cabrera.

Members of my committee, thank you for your attention and thoughtful feedback.

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Chapter 1

Why Low Rates of Student Success in Developmental (Remedial) Math in Community Colleges Matter and How this Mixed Methods Research Offers Suggestions for Improving Student Educational Attainment

1.1 Introduction and Problem Statement

Almost half of all college students in the U.S. attend community colleges (National Center for Education Statistics, 2011). When a prospective student attempts to enroll in a community college, one of the first steps is nearly always to take a placement exam in English and math. About 60% of students who take the placement exam don't score above the cut-off to enter college-level courses directly and are instead referred to developmental (aka remedial or precollege) math or English (Attewell, Lavin, Domina & Levey, Washington State Board for Community and Technical Colleges, 2012; Bailey, Jeong, & Cho, 2010). While some students score high enough to need just one remedial course, others may face as many as three or four courses in a sequence before being deemed "college-ready" by passing the last class before the college level. These long sequences, which typically have low success rates in the individual courses, are one key reason why only five percent of full-time community college students earn an associate's degree within two years (Complete College America, 2014). Many more students attend part-time with even lower completion rates.

Success Rates

Research overall finds some small success of remediation, particularly for students who are at the lower entering ability level. Most peer-reviewed studies employing rigorous

methodology find some modestly positive results of those who enroll in remedial sequences compared to controls on outcomes like subsequent course completions, credit accumulation, grades in subsequent classes, and community college graduation. However, they also find that only small numbers of students are able to persist through the remedial sequences to be rewarded with these modest benefits.

The topic of developmental education, and particularly the poor outcomes for students assigned to these sequences, gained attention in recent years with publication of two major studies — one using data from the National Education Longitudinal Study (NELS:88) (Attewell, Lavin, Domina, & Levey, 2006) – that included students at 4-year as well as 2-year colleges, and the other based on data from more than 250,000 first-time students at community colleges participating in the *Achieving the Dream: Community Colleges Count* initiative (Bailey, Jeong & Cho, 2010). In the *Achieving the Dream*² sample, representing 250,000 students from 57 colleges in seven states, only 31 percent of students completed the math developmental education sequence to which they were assigned within three years (Bailey, 2009). Students starting math three courses below college level had only a 17 percent rate of completing the developmental sequence to which they were assigned, while students who started one-level below college level had a 45 percent completion rate (Bailey, Jeong, & Cho, 2010). Moreover, many students who are referred to developmental education never enroll in it (Bailey, Jeong & Cho, 2010).

A study using data from the National Educational Longitudinal Study (NELS:88) examined students who had actually *enrolled* in developmental education, as opposed to having

² Achieving the Dream is a foundation supported, non-profit organization currently active in 37 states and over 200 community college campuses that aims to infuse evidence-based reform practices in community colleges.

been referred. Less than one fourth of the enrolled developmental education community college students in the NELS sample completed a degree or certificate within eight years of such enrollment (Attewell, Lavin, Domina & Levey, 2006). For two-year colleges, taking remedial classes was not associated with less academic success, students who enrolled in these classes did just about as well as comparable students who did not in terms of degree completion. However, they spent time and money in developmental education that could have been directed elsewhere since the comparison suggests they did not need the remedial classes.

In four-year colleges, there are negative effects of remedial coursework, but many minority students who complete a bachelor's degree do so after taking remediation. Despite some success, the researchers also found that many who complete one remedial course fail to show up for the next course in the sequence. What is more, many students who complete their developmental courses do not go on to enroll in the associated college-level courses (Attewell, Lavin, Domina, & Levey, 2006).

Since these first two major studies, other researchers have mostly confirmed the largely unencouraging results. The preponderance of the evidence seems to point to a mostly ineffectual system of developmental education.

Prevalence

The numbers of community college students in developmental math education nationally are huge. Approximately 43% of national first-time postsecondary enrollees were in community colleges in 2012 (NCES, 2013). At the height of the 2007-2011 enrollment boom, in 2011, about 7.8 million students enrolled in community colleges in the U.S. (Mullin, 2012). Estimates place the number of students enrolled in developmental math nationally at as many as 3.5 million

(Knapp, Kelly-Reid & Ginder, 2012). The percentage of students attending community colleges has been increasing primarily because many of the fast-growing states—such as California, Texas, and Florida—rely heavily on community colleges. California, for example, enrolls two-thirds of its college freshmen in its community college system (National Center for Education Statistics, 2011).

According to the National Center for Education Statistics (NCES, 2011), 98% of U.S. community colleges offer developmental education courses and services for underprepared students. In Washington, each of the 28³ community colleges offer extensive developmental education programs. In 2010-11, the year before the data in this study begins, 77,133 students enrolled in any pre-college math or English class in Washington. Forty-five percent (34,473 students) of this total headcount were under 22 years of age. The majority of these younger students, 20,575, had just graduated from high school the year before. In Washington, 46% of students who went directly to community college after high school were required to take a remedial math course (Washington State Board for Community and Technical Colleges, 2010). The problem was worse two years later when 51% of students enrolled in a developmental math class (Washington State Board for Community and Technical Colleges, 2012b). Despite this high percentage of recent high school graduates needing remediation, over 55% of students in developmental education in WA have been out of high school for more than three years (Washington State Board for Community and Technical Colleges, 2012b).

Inequity in enrollment, and completion

³ Pierce College has two campuses, one in Fort Steilacoom and one in Puyallup. In the data I examine Pierce is considered one college. There are also five Technical Colleges in the state that are not studied here due to their different incoming student population.

Minority and low-income individuals (who represent the fastest-growing demographics in the United States) disproportionately enroll in pre-college coursework at community colleges. Higher percentages of Black and Hispanic undergraduate students (45% and 43%, respectively) than Asian students (38%) or whites (31%) reported that they had ever taken a remedial course (Aud et al., 2011). At least one study found that African American students are less likely to progress through their full remedial sequences (Bailey, Jeong & Cho, 2010).

High Costs

Developmental education courses are also expensive, taken as a whole. Precollege math Full-time Equivalent Enrollments (FTEs) totaled 11,256 in 2011 in Washington. The total cost per FTE is \$4,590 (combining state and tuition dollars), with the state spending \$3,187 per FTE. Therefore, pre-college math courses cost the state approximately \$35.87 million in 2010-2011. The funding for these expenditures comes from the state general fund; students paid an additional \$15.79 million that year in tuition (Washington State Board for Community and Technical Colleges, 2012b). Thus, the total expenditure was over \$51 million.

Unclaimed Potential Benefits of Higher Education

Developmental education students may never benefit from labor market returns gained by individuals with higher education. Substantial economic and social benefits accrue to individuals with higher levels of educational attainment (Goldin & Katz, 2008; Bureau of Labor Statistics, 2012). Labor market returns correlate strongly and positively with each additional degree earned, and occupational forecasts show that the majority of jobs (63%) in 2020 will require some postsecondary education (Carnevale, Smith, and Strohl, 2010). For decades, studies have indicated that the majority of jobs of the future will demand high-level knowledge and skills

requiring some postsecondary education. For individuals, obtaining a postsecondary credential is needed to achieve middle-class status; nationally, such credentials are needed to boost economic competitiveness but failure to progress out of developmental education halts a student's progress to a credential.

National College Completion Agenda

Beginning in 2008, a wide variety and unusually large number of organizations began to adopt a “college completion agenda.” Spurred by President Barack Obama and funded by major foundations, they are undertaking diverse activities aimed at a common goal: to significantly increase the number of adults in the United States who have earned a postsecondary credential⁴. Along with many governors, private businesses and higher education systems and institutions, they are part of a growing national movement focused on increasing student success and educational attainment. Recent titles such as “Remediation: Higher Education’s Bridge to Nowhere,” a report issued by Complete College America, is representative of the press that developmental education has garnered in the last several years (Complete College America, 2012). Concerns about low completion rates have been moving this country from its traditional focus on increasing educational access to new interest in educational attainment. This is expressed not only in terms of institutional graduation rates, but also in terms of meeting state and national educational attainment goals. As such, the emphasis has shifted from “access” goals to “college completion” goals.

⁴ While specific goals of each initiative vary, each seeks to increase the percentage of college graduates in the U.S. and/or shrink achievement gaps in college attainment. For example, The Lumina Foundation for Education along with 20 funding partners is leading the Achieving the Dream initiative that seeks to help more community college students, particularly low-income students and students of color, stay in school and earn a college certificate or degree. Other initiatives include College Completion Agenda, College Completion Challenge, ACE Commission on Education Attainment, Access 2 Success, Complete College America, Project Win-Win, Complete to Compete, etc.

Legislative response

While the prevalence, seemingly small benefits, and costs of these programs to states and students are motivators for this study, heightening the need to understand program variation is recent legislation in Washington and elsewhere in response to the completion agenda that allocates funding to institutions based on student outcomes. In Washington this pay-for-performance funding scheme, while still a small but growing percentage of funding overall, awards colleges “points” for moving students through a series of milestones. In this scheme, known as the Student Achievement Initiative (SAI), the Washington State Board for Community Colleges (WASBCTC) monitors student point accumulation and awards modest amounts of funding to institutions based on their accumulation of points. Annual funding for SAI points now stands at 5.25 million (WASBCTC, 2014).

1.2 Purpose and Overview of this Mixed Methods Dissertation

The research outlined here uses a mixed methods approach to both qualitatively and quantitatively describe and analyze the variation in math developmental education programs in Washington, examining which programmatic and institutional characteristics seem to be associated with the greatest success, while controlling for student background characteristics. Math was chosen as the subject area of focus because of the large student population and high rates of non-completion in this core subject.

The purpose of this study is to investigate to what extent student characteristics versus program and policy factors influence student success outcomes. It may be that program level policy and practice variables play only a very small part in achievement of student outcomes and therefore the accumulation of points. The implication would be that the performance funding

initiative may be rewarding colleges simply for enrolling more promising students. Investigating the sources of institutional variation can help disentangle school effects from the effects of intake characteristics of students who attend a particular community college. Under the college completion mandate and particularly these increasingly popular and prevalent pay for performance mechanisms in higher education, it is imperative that studies of school effects examine whether and how schools can use policy and practice variables to influence students' academic performance.

In addition to determining what amount of variance in outcomes is attributable to student vs. program characteristics I also hope to determine what program and policy variables or set of variables seem to be positively associated with student success and determine whether there is a typology or set of *policy posture categories* with regard to developmental education that seems to be associated with student outcomes. Because policy and practice variables are often nuanced and not susceptible to being accurately or entirely captured in quantitative data, I employ a sequential mixed methods strategy to enrich, amplify and add depth to my quantitative findings.

I performed case studies at three community colleges, two with better than expected performance (controlling for student characteristics), and one more average performer. Case studies allowed me to paint a more accurate, and detailed picture of developmental math programs in practice. Case studies included observations of classrooms and meetings and interviews with students, faculty and administrators to determine how policies and practices play out within the context of developmental math education programs in the three programs under study. Using this approach I both describe the variation in the programs and shed light on what policies and practices students, instructors, and administrators find especially salient to student success. Using this mixed methods approach, I describe a range of current developmental math

programs in practice and offer suggestions based on the qualitative and quantitative findings for a math developmental education model that ultimately has more promise to increase student educational attainment.

Chapter 2

Mapping the Landscape: What We Know About Developmental Math Programs

Pre-college education courses offered in American community colleges are designed to boost the skills of students who enter college without sufficient English or math skills to perform “college-level” work. The idea of pre-college education is simple: if the entry test assesses a student as not having the skills to enter college-level courses they are referred to courses below the 100 (college)-level, for math, reading or English, and sometimes all three. According to the National Center for Developmental Education at Appalachian State University, “developmental education supports the academic and personal growth of underprepared college students through instruction, counseling, advising, and tutoring. The clients of developmental education programs are traditional and nontraditional students who have been assessed as needing to develop their skills in order to be successful in college” (National Center for Developmental Education, undated). Unfortunately, experts and institutions do not agree on the meaning of being “college ready,” and policies governing assessment, placement, pedagogy, staffing, completion, and eligibility for enrollment in college-level, credit-bearing courses vary from state to state, college to college, and program to program. This is true across the Washington state community college system as well.

2.1 Theories and Approaches to Program Design and Pedagogy

Literature on theories of program design and pedagogy in developmental education assert (at least) four different perspectives on remedial education programs. The small amount of extant research describes pedagogy and program design that varies from holistic models guided by

student development theory (Higbee, Arendale, & Lundell, 2005; Center for Research on Developmental Education and Urban Literacy, 2001) to “skills and drills” models guided by a deficit theory emphasizing part-to-whole instruction and more time on task to overcome deficiencies (Grubb, 1999; Grubb et. al, 2011b). Other authors assert that inexplicit and largely unintentional theoretical frameworks guide developmental education practices and that there is no strong consensus or widely accepted theory about how to carry out developmental education most effectively (Arendale, 2008; Chung, 2005). Partly as a result, the content and organization of remediation varies widely (Bailey, 2009). While still other authors, especially those focused in tutoring or academic skills centers, describe a transformative or multicultural approach (Center for Research on Developmental Education and Urban Literacy, 2001; Higbee, Arendale & Lundell, 2005; Bruch et al., 2004).

Proponents of developmental education view it as a comprehensive model focusing on development of the person in both the academic and affective domains (Boylan, 1999) that assumes that each student has skills and knowledge that can be developed (Arendale, 2008). Astin's (1985) theoretical work has been a primary source of knowledge about college student development. He proposed that, instead of viewing higher education as a place to produce "knowledge and trained manpower," educators must embrace a "talent development model," recognizing that where students begin along the educational continuum is not as important as how much they learn and develop (1985, pp. 14, 16). As he noted, "Under this model, the major purpose of any institution of higher education is to develop the talents of its faculty and students to their maximum potential.... The verb develop seems more appropriate than the verb produce" (1985, p. 16). This idea is shared by other experts, e.g. Hunter Boylan from the National Center for Developmental Education, “Developmental education is the integration of academic courses

and support services guided by the principles of adult learning and development” (Boylan, 1999).

In case studies of five “highly effective” community colleges selected from a survey pool of 36 for their reputation for excellent collaboration between basic skills and developmental units, Boylan (2004) found “a philosophy in which student needs are considered first. Decisions are made in terms of what is in students’ best interests rather than what is in the best interests of the faculty. Students are central to the learning process (Boylan, 2004; p. 25). It is important to note that Boylan only looked at “exemplary” colleges and that he did not observe any courses, instead his research was conducted through interviewing program administrators and faculty members.

However, based on case studies in 13 California community colleges where researchers interviewed administrators and instructors *and* observed classrooms, Grubb et al. (2011b) saw little evidence of student development theory at work in math basic skills classrooms.⁵ Historically, developmental education arose in the late 1800’s to “remediate” those students entering college with inadequate or uneven high school instruction (Arendale, 2008). Grubb saw evidence that this historical model is still the dominant method. Grubb and his colleagues describe the approach to developmental and basic skills education they saw as “remedial pedagogy.” In remedial pedagogy the emphasis is on small sub-skills in part-to-whole instruction, the absence of much attention to competencies that were not judged to be basic (like

⁵ Basic skills (AKA Adult Basic Education or ABE) courses are one step lower than developmental math. In math they typically serve students interested in taking the GED exam, although there is overlap between low-level developmental math courses and basic skills courses. ABE is usually defined as equivalent to grades 1-8 in level of content and assists adults in obtaining the knowledge and skills necessary for work, further education, family self-sufficiency, and community involvement. ABE develops skills in reading, writing, math, speaking/listening in English, GED and Adult High School completion, and solving problems in technology rich environments. Developmental courses, defined as equivalent to grades nine through twelve, prepare students to transition into college-credit courses (WAWASBCTC, undated). In this paper I occasionally use the term “pre-college” to refer to the entire range of math courses before the college level.

analytic and conceptual abilities), the technique of drill and repetition, and the lack of any applications to the world outside the classroom. This led to classes that were quite traditional, “where only the most motivated students could stick through semester after semester of such teaching” (Grubb et al., 2011b p. 55). He concluded that the “dominance of remedial pedagogy . . . suggests that inadequate instruction is at least partly responsible for poor progress in basic skills sequences” (Grubb, et. al, 2011b p. 11). He argued that despite student development rhetoric developmental education units in the main continue a historic model focusing on the student’s deficits.

Although most developmental educators are knowledgeable about the theories that guide their academic disciplines, many admit to lacking training in educational and related theories and do not perceive that there are many professional development opportunities to learn more about such theory (Chung and Higbee, 2005). Chung (2005) asserts that developmental education is, overall, presented to the public as a "necessary evil" (p. 17) that exists due to the poor education students receive in high school, that requires an exorbitant proportion of taxpayer dollars, and that ought to be limited in scope. This pejorative picture is presented to the public in a number of recent publications (Complete College America, 2012; Charles A. Dana Center with Complete College America and Education Commission of the States and Jobs for the Future, 2012). Chung argues that part of the answer to why developmental education is so negatively viewed involves the paucity of theoretical discussion and the lack of a shared theoretical framework among developmental education and learning assistance professionals. He argues for a practitioner driven theory but does not endorse any specific framework (Chung, 2005).

Another group of theories that has been used to describe developmental education are “transformative theories” (Higbee, Arendale, and Lundell, 2005). Drawn from democratic theory

and multicultural education theory, transformative education, philosophically at least, places the student's reflective processes at the core of the learning experience and asks the student to evaluate both new information and the frames of reference through which the information acquires meaning (Duranczyk, Goff & Opitz, 2006). An example occurred at the developmental math tutoring center at the University of Minnesota where students were encouraged to use their cultural knowledge and experiences, as well as their intuitive language and understanding, to discuss mathematics and thereby achieve a more in-depth understanding of "academic" mathematics. Assumptions about students' mathematics ability or aptitude were not made based on entry-level mathematics skills (Duranczyk, Goff, & Opitz, 2006). However, this type of teaching can be difficult, particularly in mathematics classrooms where programs focus on foundational skills that “seem to be stable, objective and best taught separately from social political and cultural dynamics of access. Math and hard sciences especially are particularly difficult to fit into a multicultural framework” (Bruch, Jehangir, Jacobs, & Ghare, 2004).

Unfortunately, neither in the research literature nor in the community of instructors other than in recent work by Grubb focused on basic skills classrooms is there much description and analysis of classroom practices in pre-college education or of their underlying theory or approach. There has been relatively little research that describes community college classrooms and — except where individual departments have organized themselves to improve instruction, such as in some of the “innovations” described later — there is no tradition in community colleges (or in most formal schooling) of instructors visiting each other's' classes to understand what happens there (Grubb et al, 2011b).

Organization

In Washington, most developmental education programs and courses are governed by their own campus level policies, including those for cut-off scores for placement into multi-level sequences of courses, course content, requirements to pass into college level courses, and policies governing transition from English as a Second Language (ESL) or Adult Basic Education (ABE) to the more advanced developmental courses. A student may be judged ready for English 101 at one college and told to enter a remedial course in the college just down the road. In some cases a student may have to take fifteen pre-college credits while in others, five credits will suffice. Pre-college education is organized into many levels of courses that differentiate students at what are essentially progressive grade levels. This model assumes that the entering assessment test can accurately place a student in the correct level and that the pedagogy and curriculum in that level is directly linked to the assessment and to skills needed in subsequent developmental and college-level courses.

The most common developmental education model in Washington also employs the idea that the majority of students need more time on task with math irrespective of their particular interests or aspirations in other fields, and that the instructor best determines classroom activities and assesses when the student is ready for the next level of the sequence or is college ready. In many other aspects, for example, who is qualified to teach, what support services are offered or mandated, and how to organize developmental education, colleges have had wide latitude to develop their own policies and practices. While many of the traditional practices have begun to change with recent concern over low student success rates, the great majority of developmental education students in Washington and nationwide are still enrolled in multi-sequence, instructor-driven courses.

In practice, pre-college education programs at the majority of community colleges encompass three groups with overlapping and sometimes internally disputed boundaries. Pre-college programs are typically thought of and organized in most community colleges into Developmental, Adult Basic Education (sometimes including GED courses) and ESL courses. Developmental (aka remedial) is the highest level of pre-college education offered. Colleges usually also offer a group of courses below developmental known as Adult Basic Education (ABE). Depending on the state or the individual college, ABE courses may include ESL students or GED students or those students may be considered a completely separate group. ABE students may be found, like developmental students, in either English or math. However, Boylan points out “there is a sizeable gray area where services overlap and students can enroll as easily in one as the other” (Boylan, 2004, p. 4). In Washington, developmental courses are defined as “Pre-college courses which prepare students for college-level classes,” while Basic Skills are “courses which enable adults to overcome illiteracy (ABE) or complete high school, or provide English proficiency to those whose native language is not English (ESL).” (Washington State Board for Community and Technical Colleges 2012b). In Washington, the area of basic skills is one of the State Board for Community and Technical Colleges’ mission areas, along with college transfer and workforce education (Washington State Board for Community and Technical Colleges, undated, b).

Over the past two decades, developmental education in Washington has at different times been the responsibility of a state group known as the Council for Learning Assisted Systems, the Council for Basic Skills, and the professional group the Washington Association for Developmental Education. Currently, pieces of the program fall within the purview of three branches of the State Board for Community and Technical Colleges (WASBCTC) (Assessment,

Teaching and Learning; Adult Basic Skills; and Transfer) and two councils (Articulation and Transfer and Council for Basic Skills). A similar fragmentation exists at the local level, with many campuses artificially drawing fuzzy, overlapping, or disputed organizational boundaries between segments of sequences of reading, writing, and mathematics curriculum. This fragmentation extends in some cases to differing workload requirements in faculty contracts for faculty teaching at the lower ends of the curriculum sequence. According to the National Study of Developmental Education II, a survey of 29 developmental education programs conducted by researchers from the National Center for Developmental Education at Appalachian State University, just under half of institutions surveyed had developmental education programs that were centralized in a “department,” while the majority had a diffuse organizational structure (Gerlaugh, Thompson, Boylan, Hildreth, 2007).

Funding

In Washington, developmental education courses are funded the same way almost all other campus classes are, through student Full-Time Equivalent (FTE)-based general fund reimbursement and student tuition. In general, faculty who teach developmental education courses are part of English and math departments, sometimes teach both developmental education and college-level courses, and are funded as are other academic instructors. In contrast, basic skills courses are funded through an array of sources. Most basic skills courses (including all ESL courses) only cost students in Washington State twenty-five dollars per quarter so student tuition funds are a very small portion of funding. Because of the rules governing the acceptance of federal funding, all tuition money collected in basic skills has to be given to basic skills programs. For an average sized college in the Washington state system, that’s about fifty thousand dollars per year. The majority of funding comes through the state and

federal funds. As a rule, basic skills faculty teach only basic skills; they don't float between basic skills and developmental education courses or basic skills and college-transfer courses.

Faculty

Part-time faculty members teach the majority of pre-college courses. In fall quarter 2012 in Washington, 30.3% of basic skills instructors in community colleges had full-time contracts compared to 61% of workforce education faculty and 52% of academic faculty (Washington State Board for Community and Technical Colleges, 2012a). In the National Study of Developmental Education II, respondents indicated that only 21% of all developmental courses were taught by full-time faculty (Gerlaugh, Thompson, Boylan, Hildreth, 2007). The existing research suggests that the most successful developmental education programs employ the highest percentage of full-time faculty (Boylan, 2002). Research also suggests that overuse of part-time faculty has a negative effect on student retention (Jacoby, 2006).

Other than that they are more likely than other academic or technical faculty to be part-time, virtually nothing else is known about who teaches developmental math courses. Their qualifications, training, experience, backgrounds, and relative pay levels have not been described in research.

Placement and Referral

Of the 29 community and technical colleges nationwide in the National Study of Developmental Education II, over 90% reported that assessment testing is mandatory and used to place students into pre-college coursework (Gerlaugh, Thompson, Boylan, Hildreth, 2007). This survey is the best data available as it represents 29 institutions in 29 different states. According to the authors "institutions were selected for participation by systematic circular sampling, allowing for the results to be generalized to all developmental programs at 2-year institutions."

Through this procedure, 45 institutions were selected to participate in the study. Of those, 16 were unable to produce sufficient data required for the study, thus the results represent 64.4% of the originally intended sample (Gerlaugh, Thompson, Boylan, Hildreth, 2007, p.2). The surveyed institutions utilized a variety of assessment instruments to determine where to place students in math. The most common are American College Testing's (ACT) COMPASSTM and the Educational Testing Service's ACCUPLACER® – these two methods were used by 97% of the institutions. In addition to these two tests, 21% of the institutions developed their own assessment. Only 7% of institutions used noncognitive assessments as part of their assessments (Gerlaugh, Thompson, Boylan, Hildreth, 2007). In Washington, 24 of the state's 28 community colleges place students primarily through the COMPASS or the ACCUPLACER.

Although over 90 percent of two-year institutions use the results of assessment tests for placement into remedial education (Parsad, Lewis, & Greene, 2003; Gerlaugh, Thompson, Boylan, & Hildreth, 2007), there is limited evidence on the predictive validity of these test scores (Hughes & Scott-Clayton, 2010). According to a review by Noble, Schiel, and Sawyer (2004), "Using multiple measures to determine students' preparedness for college significantly increases placement accuracy for example, test scores and high school grades may be used jointly to identify students who are ready for college-level work" (p. 302). Belfield and Crosta found that using high school GPA for recent high school graduates was a more accurate predictor of student performance than assessment scores (Belfield and Crosta, 2012).

States and institutions use many different assessments, but even when they use the same assessments, institutions often set different cutoff scores (Ewell, Boeke, & Zis, 2008). Moreover, there is no obvious point in the distribution of cutoff scores that might provide meaningful information to distinguish between "remedial" and "college-ready" students, although

institutions largely act as if there was. The difference between students assigned to a developmental vs. a college-level course is sometimes the difference of one point on an exam. Thus, there is little to differentiate students so as to place them within the wide range of students above and below the cutoff scores (Bailey, Jeong & Cho, 2010), or within the sometimes many levels of developmental courses. Administrators and faculty members at an institution develop cut-off scores so that a student falling above or below a particular score can be assigned to a particular pre-college level. A student may be ready for English 101 at one college but told to enter a remedial course in the college just down the road due to different placement tests and cut scores. In some colleges then a student may have to take fifteen credits of developmental coursework while in others, five credits would suffice for the same student.

A report by Hughes and Scott-Clayton determined that internal and external pressures are pushing a trend toward state standardization of assessment and placement (2010), but that may also have the unintended consequence of limiting experimentation. An example is courses where students who represent many levels of developmental education are placed together in one class and the instructor assesses each student individually through a checklist of competencies. And even if assessment and placement systems are standardized, it does nothing to address the problem of a lack of predictive validity.

Student Population and Need

As noted earlier, around 40% of U.S. college students attend community colleges and nearly 60% of these students attend at least one developmental education course (NCES, 2013; Attewell, Lavin, Domina & Levey, Washington State Board for Community and Technical Colleges, 2012; Bailey, Jeong, & Cho, 2010). Despite low funding and high rates of part-time faculty, pre-college courses have perhaps the highest-need students in community colleges.

When one observes or teaches in a developmental classroom the most striking aspect is the heterogeneity of students. Some are “brush-up” students, who simply need to remember skills they have already learned. Some have been misplaced by placement exams, and similarly need very little additional instruction (Belfield and Crosta, 2012). Many have failed to learn certain academic skills in K-12 education. Others have learning disabilities or mental health issues, and community colleges have very few resources to either diagnose or treat such conditions. The result is that the classroom contains many students with different needs, while the instructor has only varying instructional approaches to offer (Grubb, 2013).

There are many reasons why students need developmental coursework, but a primary cause is the misalignment between high school and college expectations. Systems in K-12 were never designed to prepare all students for college, and students may meet all high school requirements and be admitted to college, only to later discover that they cannot pass placement tests for entry into college-level courses. The need for developmental education also stems from the large numbers of adult workers who need additional education and upgraded skills to be successful in a competitive job market. In addition, immigrants may need skills development to be ready for college-level work (Russell, 2008).

Compounding this remediation problem is the fact that many community college students today, compared with their peers at four-year institutions, are less likely to have the information and preparation they need to succeed in college. Community colleges serve a large proportion of low-income, ethnic minority, and first-generation college students. These student populations are less likely to receive college counseling, be placed in college-preparation courses, and obtain information about college admissions and placement (Kirst and Usdan, 2009). Increasingly, four-year institutions transfer their remediation to community colleges. At least ten states discourage

four-year universities from offering remedial education by not providing state funding for such purposes (Jenkins and Boswell, 2002).

Effectiveness

Research findings overall find some small success of remediation, particularly for students who are at the lower entering ability level and who manage to complete the dev sequence. Most peer-reviewed studies find some modestly positive results on outcomes for completers like subsequent course completions, credit accumulation, grades in subsequent classes and graduation, when employing rigorous methodology. However, they also find that small numbers of students are able to persist through the remedial sequences to be rewarded with these modest benefits.

As touched on briefly in the introduction, the topic of developmental education, and particularly the poor outcomes for students assigned to these sequences, gained attention with two major studies — one using data from the National Education Longitudinal Study (NELS:88) (Attewell, Lavin, Domina, & Levey, 2006) and the other based on data from more than 250,000 first-time students at colleges participating in the *Achieving the Dream: Community Colleges Count* initiative (Bailey, Jeong & Cho, 2010). Both of these studies indicate that nearly 60 percent of students take at least one developmental education course during their community college career (Bailey, Jeong & Cho, 2010; Attewell, Lavin, Domina & Levey, 2006). This large number of students and the seemingly poor performance of students in these courses drew national attention to pre-college education coursework.

In the *Achieving the Dream* data, Bailey, Jeong, and Cho found that only about 60 percent of students who tested at a developmental level actually enrolled in the remedial course to which they were referred. The results also show that more students exit their developmental

sequences because they did not enroll in the first or a subsequent course than because they failed or withdrew from a course in which they were enrolled (Bailey, Jeong & Cho, 2010). Many who complete one remedial course fail to show up for the next course in the sequence. Overall, less than one half of students who are referred to developmental education complete the recommended sequence. In fact, in the Achieving the Dream sample, only 31 percent of students completed the math developmental education sequence to which they were assigned (Bailey, Jeong & Cho, 2010).

However, this study data did not have present complete information about what was required to complete a credential in some cases. Students may take a mandatory assessment test and be “referred” to a developmental sequence but because of the specific degree or certificate they are pursuing, they may not need to take any math or English courses. For example, a student wishing to enroll full-time at Bellevue College in Washington is required to take an assessment entrance exam but upon meeting with an advisor may learn that to pursue an Associate’s Degree in a number of technical fields they do not need to take any English or math. Therefore they may not enter the sequence to which they were referred.

In the journal article by Bailey, Jeong and Cho, students are described as “credential seeking” but what that means is not defined. Therefore, as I understand it, a student could be seeking a 1-year (or even less) credential that requires no English or math courses. A student who doesn’t enroll in the sequence to which they were assigned is not necessarily a failure for that sequence; they may not have needed to enroll in the sequence to achieve their goal.

It is also possible that a student only needed to take one course to achieve their goal. Consider Lake Washington Institute of Technology where English 093 (one level below college-level English) is the requirement for nearly every one-year technical degree. Because neither the

analysis of Achieving the Dream data nor the analysis of NELS:88 data (Attewell, Lavin, Domina, & Levey, 2006, discussed below) appear to have data that considered student intent they both likely overestimated the number of students who “failed” in reaching their goal of college-level English or math because (again, as I read the articles) both studies, probably due to limitations in their data, assumed that all students in their sample had the goal of completing college-level English or math to achieve their credential.

The National Educational Longitudinal Study (NELS:88) only examined students who had enrolled in developmental education, as opposed to all those who were referred. Less than one fourth of developmental education community college students in the NELS sample completed a degree or certificate within eight years of enrollment. In comparison, almost 40 percent of community college students in the NELS sample who did not enroll in any developmental education course completed a degree or certificate (Attewell, Lavin, Domina, & Levey, 2006).

In another study, by Calcagno and Long, the researchers employed a regression discontinuity design to examine the outcomes of nearly 100,000 college students in Florida. Being assigned to remediation appears to increase persistence to the second year and the total number of credits completed for students on the margin of passing out of the requirement, but it does not increase the completion of college-level credits or eventual degree completion. The results suggest that remediation might promote early persistence in college, but it does not necessarily help students on the margin of passing the placement cutoff make long-term progress toward earning a degree (Calcagno and Long, 2008).

In another paper that found negative effects of dev ed placement, the authors used longitudinal administrative data from the state of Texas and a regression discontinuity design that exploited the sharp test score cutoffs used to assign students to remediation. Aside from weak evidence that remediation improves the grades received in college-level mathematics courses, they found little indication that students benefit from remediation. Their estimates indicate that remediation has a minimal impact on the years of college completed, academic credits attempted, receipt of an academic degree, and labor market performance (Martorell and McFarlin, 2011).

Other studies of the effectiveness of developmental education have found more mixed or even positive results, however. In a study by Bettinger and Long using a unique dataset of approximately 28,000 students in Ohio, the results suggest that students in remediation are more likely to persist in college in comparison to students with similar test scores and backgrounds who were not required to take the courses. They were also more likely to transfer to a four-year college and to complete a bachelor's degree (Bettinger & Long, 2005).

Using a hierarchical multinomial logistic regression design, Bahr (2008) analyzed data that address a population of 85,894 freshmen, enrolled in 107 community colleges in California, comparing the long-term academic outcomes of students who remediate successfully (achieve college-level math skill) with those of students who achieve college-level math skill without remedial assistance. He found these two groups of students experience comparable outcomes, which indicates that remedial math programs (when completed) are effective at resolving skill deficiencies. In 2010 the author used the same dataset to look at students who were deficient in both English and math and who had multiple levels of developmental education to move through to achieve college-level. In the second study he found a disproportionate number of students did

not make it through the remediation sequence. For those who did, remediation was efficacious with respect to ameliorating both moderate and severe skill deficiencies, and both single and dual skill deficiencies (Bahr, 2010). The students go on to acquire two-year credentials and to transfer to four-year institutions at rates that are comparable to those of college-prepared students who attain similar math and English competency. In other words, even students who are sorely underprepared for college coursework, even in multiple skills areas, may succeed beyond what one would predict based on their initial course placements (Bahr, 2010) but these students who do make it through were very few in number.

In another study that examined students in two-year and four-year public institutions in Tennessee, Boatman and Long (2010) found negative effects on long-term college persistence and degree completion. However, at the lowest end of the academic ability spectrum, the negative effects of remediation were much smaller and not significant on the outcomes of persistence, degree completion, and college GPA.

In a study of six community colleges in a single district in New York, Scott-Clayton and Rodriguez found that remediation does little to develop students' skills. But they also found relatively little evidence that it discourages either initial enrollment or persistence. Instead, they find the primary effect of remediation appears to be diversionary: students simply take remedial courses instead of college-level courses. These diversionary effects are largest for the lowest-risk students (Scott-Clayton & Rodriguez, 2012). In their paper Scott-Clayton and Rodriguez (2012) also raise methodological concerns about the instrumental variables or what they call "fuzzy" regression discontinuity design in which cutoff-based remedial assignments are used as an instrument for actual remedial enrollment (for example in Calcagno & Long, 2008; Martorell & McFarlin, 2011). They argue that, "a key assumption needed to justify such an approach is that

remedial assignment has no effect on future outcomes except through its effect on remedial enrollment; however, in many contexts . . . this assumption is unlikely to hold.” (Scott-Clayton & Rodriguez, 2012, p. 14).

Despite these methodological concerns, the preponderance of the evidence does seem to point to a mostly disappointing system. Especially for students who may be close to not needing remediation or who do not enter with very low skills, remediation might be more of a barrier to earning college credit than it is a help in boosting academic skills. This is not surprising given the reliance on part-time faculty who may have limited training, low levels of funding and high costs to students, high student needs, confusing organizational systems and levels, lack of agreement over college-readiness and relatively low levels of support for faculty, administrators, programs and students alike.

2.2 Intervention Strategies⁶

In order to address the myriad of potential sources of the current perceived ineffectiveness of developmental education math programs, a number of intervention approaches have been recently proposed and implemented. Most interventions have not had a well-articulated theoretical basis and most have met with disappointing evaluation results. Interventions have focused on specific aspects to explain developmental students’ lack of progression, including inadequate student test preparation, insufficiently predictive exams, poorly aligned curricula, uninspiring skill-and-drill instruction, and the sheer length of time and financial resources required to finish a long sequence of noncredit courses (Kirst and Usdan,

⁶ Many different intervention strategies have been described in research. I limit my descriptions to those that have empirical evidence to support them and which I found to be occurring as policy or practice in Washington. For a full inventory of program and policy offerings offerings by Washington community college see the appendix.

2009; Grubb, 2011b; Hughes & Scott-Clayton, 2011; Complete College America 2012). Each explanation implies that the developmental system is broken in a certain way and that one or more specific fixes will mend it. However, as Chung asserts, the lack of a theoretical framework for what developmental education hopes to accomplish and how might be a bigger problem (Chung, 2005). In addition, Jaggars and Hodara (2011) identify three sets of opposing forces that shape developmental education policy and practice: system-wide consistency versus institutional autonomy, efficient versus effective assessment, and promotion of student progression versus enforcement of academic standards. They argue that while these goals may not be absolutely irreconcilable, they tend to work in opposition to one another and may create frustration on the part of administrators and faculty, confusion on the part of students, and poor outcomes overall (Jaggars and Hodara, 2011).

To better address student needs, more needs to be known about whom developmental education students are in order to devise effective theory and practical interventions. It seems from available data that developmental education students are on average, older and more diverse than the general student body at community colleges (National Center for Education Statistics, 2011; Washington State Board for Community and Technical Colleges 2010; Washington State Board for Community and Technical Colleges, 2012a). As Renn and Arnold (2003) point out, “Students entering college immediately after high school generally have different roles and family expectations than students who enter after working for several years, marrying or partnering, and perhaps rearing children.” A number of scholars have also detailed the importance of culturally relevant pedagogy since Wlodkowski & Ginsberg first made the higher education case for this in 1995 (Wlodkowski & Ginsberg, 1995).

Few studies provide a comprehensive view of students in developmental education. Much of the current policy discussion in state legislatures and colleges focuses on the problem of states paying for the same education (e.g. high school math) in both high school and in developmental education courses in community colleges. However, examination of the data in Washington suggests that the majority of students in developmental education math courses have been out of high school for more than three years, suggesting that students may have received adequate math instruction in high school and need more of a refresher rather than to attend many levels of coursework. It may also be the case that approaches need to be tailored to student populations in a more deliberate way.

There is currently a large nationwide push to reform developmental education and many interventions, both large and small scale, are being tested. There are some notable innovations that have been tried at small scale around both instructional methods and pathways reforms. To date, most interventions have assumed developmental education students to be a monolithic population with the exception of programs aimed at technical program contextualization.

It appears as though the intervention strategies that are being developed do not necessarily arise from a common understanding of what the problem is or a strong theoretical foundation. Thus, the search for solutions is likely to be problematic from the onset. Nevertheless, the following is a brief overview of current intervention efforts and what is known regarding their effectiveness.

Acceleration via Compression or Differentiated Tracks

One simple intervention strategy is to reduce the number of developmental education levels. Since many students who complete one level of remediation fail to show up for the next

level, colleges can try to accelerate movement through various levels of remediation by combining levels or perhaps eliminating any elapsed time between levels. These strategies have been shown to have positive outcomes in preliminary assessments (Zachry and Schneider, 2010). However, authors have pointed out that there are concerns with these approaches over protecting academic standards (Jaggars & Hodara, 2011). Several different acceleration models currently exist, including compressed or differentiated tracks models for students not pursuing STEM degrees which compress the developmental education curriculum into a more streamlined or even non-algebra based sequence.

One large-scale example of differentiated pathways occurs in Texas' 50 community colleges where they are working to develop and implement two alternative math pathways, as well as a STEM pathway for students with those interests who require some remediation. The starting point for each of the pathways is a remedial level math foundations course that covers numeracy, proportional reasoning, algebraic reasoning, descriptive statistics, basic probability and modeling. The course is taken in conjunction with a student success course that emphasizes building the skills and affective competencies to succeed in math and other college courses. Students in the STEM pathway are required to take an additional remedial course, equivalent to intermediate algebra, before taking a college-level pre-calculus course. But students in the other two pathways can proceed directly to a college-level math course in statistics or quantitative literacy (Burdman, 2013). Thus, they circumvent the algebra courses that are difficult for many students to pass and, it is claimed, not necessary for many academic programs or careers.

In Washington, these differentiated tracks are relatively common with slightly more than half of the colleges in the state offering this option. Some colleges have up to four different

tracks offered with different course content and fewer or more total developmental math courses depending on a student's intended certificate or degree goal.

Statway

The Carnegie Foundation for the Advancement of Teaching has developed new developmental math curriculum. The idea from Carnegie is that most students in developmental math do not need the traditional series of higher-level pre-college math based on algebra skills and instead would be better served by a quantitative reasoning or statistics curriculum. The Carnegie Foundation developed two new curriculum series to meet this need; Statway and Quantway. In 2013 there were 49 institutions in 14 states with nearly 5,000 students currently or previously enrolled in a Statway or Quantway curriculum. This is still a very small percentage of the developmental math student population nationwide (Carnegie Foundation for the Advancement of Teaching, 2013). In Washington, three colleges have a Statway option. The Carnegie Foundation has yet to publish peer-reviewed program results, although they show high rates of success in internal evaluations.

Acceleration via Modularized Units

Modularization divides traditional semester or quarter courses into discrete learning units, or modules, that are designed to improve a particular competency or skill. This approach has become increasingly popular in the last decade, particularly in restructuring developmental math courses; a number of colleges participating in high profile developmental education reform movements, such as Achieving the Dream's Developmental Education Initiative, and the Ford Foundation's Bridges to Opportunity Project have focused on ways to increase students' progress through these courses (Zachry and Schneider, 2010). Modularized courses generally allow students to prove mastery of particular skills by taking a series of short, focused assessments.

After they demonstrate competency, students can move on to more advanced modules. In North Carolina, for example, liberal arts majors need to take or pass out of only five modules; engineering majors require all nine (Alstadt, 2012). While some modularized courses are instructor-led, others implement a self-paced format, allowing students to complete particular segments of courses at their own pace. In Washington, at the eight community colleges which offer modularized courses, they almost all take place in computer labs and student lessons are delivered through software and assessed on-line.

Contextualization

Contextualized instructional models seek to help academically underprepared students progress more quickly through their developmental skill building while engaging directly with their academic or vocational field of interest (Perin, 2011a). This intervention has the added benefit of being theoretically sound. The connection of developmental instruction to applications and life goals is consistent with constructivism, which places students' interests and needs at the center of education (Dewey, 1916). From a cognitive perspective, contextualization is thought to promote transfer of learning and the retention of information (Dirkx 1998; Perin 2011a). In vocational programs, contextualized learning affords students the opportunity to gain professional or technical skills while still enrolled in their pre-collegiate programs, thus presumably speeding up their progress toward program completion.

While the evidence is still limited, rigorous research does exist about the success of contextualized learning programs. Non-experimental evaluations of several vocationally focused programs that were developed as part of the Charles Stewart Mott Foundation's Breaking Through initiative revealed promising college outcomes, such as increased rates of college readiness and increased progress toward completing occupational certificates (Bragg, 2013). A

quasi-experimental study of Washington State's Integrated Basic Education and Skills Training (I-BEST) program was conducted in 2009. The I-BEST program offers basic English instruction, including discipline-specific vocabulary training and lessons on employer and employee communications, within the context of specific workforce training classes, such as commercial driving, nursing, and early childhood education. The researchers found that students in the I-BEST programs earned an average of 14 more college credits than non-I-BEST students and had a higher probability of persisting into the second year (by 17 percentage points) and of earning an occupational certificate (by 40 percentage points) (Jenkins, Zeidenberg, and Kienzl, 2009) over a two year time period from 2006-2008. In Washington, contextualized learning is being experimented with in developmental math in seven colleges through the creation of occupational courses paired with developmental math curriculum and team-taught with two instructors (e.g. Math for Healthcare Workers).

Learning Communities

Learning Communities (where student's take courses as a cohort, often based on a theme or shared interest) and linked classes are perhaps the most theory-based intervention common in developmental education. This intervention is based largely on Tinto's theory of college student involvement (1993). In essence, the theory argues that the extent to which a student is academically and socially engaged in the institution will predict their retention. However, learning communities also seem to be one of the least effective interventions empirically. Programmatic interventions such as learning communities and linked coursework in developmental education programs in community colleges have shown modest improvements or no improvements in student outcomes (Sommo et. al, 2012; Visher et. al. 2012; Thomas Bailey, personal communication, April 12, 2012). Experimental studies have found positive though

modest impacts on students' achievement and persistence in school; learning communities that link a developmental math or developmental English class with a college-level course have resulted in improvements in the number of credits earned and in students' progression through developmental education (Scrivener et al. 2008; Weissman et al. 2011). However, these effects tended to diminish after the student finished the course.

While learning communities have been widely cited and described in literature beginning with Tinto's 1993 book, in practice they are difficult to support. Issues of student and instructor schedule complications, instructor pay and classroom teaching time overlap, instructor coordination of curriculum, antiquated computer registration systems, and low student demand have led to their declining popularity in recent years. I could find no examples of developmental education learning communities in Washington.

Academic Support

Rigorous research around tutoring and supplemental instruction strategies is limited, and the available evidence reveals mixed results on student achievement. While some promising trends have been noted for tutoring programs most studies were limited in what they could attribute to the influence of these programs versus other factors, such as student motivation or student financial and personal circumstances (Zachry and Schneider, 2010).

Achieving the Dream

Perhaps one of the largest groups of students involved in developmental math reform is found in the Achieving the Dream (ATD) - Developmental Education Initiative (DEI). Achieving the Dream is a national reform network dedicated to community college student success and completion focused primarily on helping low-income students and students of color complete their education and obtain credentials. ATD includes about 250 "member colleges" in

34 states and is primarily funded by the Lumina Foundation but has many other large “investors” including the Gates Foundation, The Kellogg Foundation, and the Charles Stewart Mott Foundation but also requires contributed funds from the institution. (Achieving the Dream, undated). The DEI consists of 15 ATD colleges and six states involved in policy work that are all participating in at least one research based intervention or reform and its evaluation (Achieving the Dream, 2013). ATD provides guidance to colleges through coaching regarding best practices, help setting up data systems and capacity for analysis, and opportunity for learning from others in the network. The interventions are being evaluated by MDRC, a large policy and evaluation group with research methodology and statistical expertise. Some of the studies with promising results cited above are interventions taking place at DEI colleges, but most of the colleges have not yet reported peer-reviewed results (Achieving the Dream, undated).

While many of the specific policy initiatives described here are recommended by ATD (for example acceleration strategies), I include ATD as a separate intervention because the overall goal of the initiative is to transform college culture into one that encourages data use and data driven decision making and a main focus of the effort has been improvements in developmental education programs. In Washington 15 community colleges are currently participating, or have participated in ATD.

Assessment and Placement

At least five states’ community college systems have developed customized placement exams that are intended to align better with college math curricula (Burdman, 2012). These include diagnostic exams in Virginia and North Carolina that divide curricula into eight or nine content modules. Instead of a test score above or below a prescribed cut-off, a student is simply given a breakdown as to which of the modules he or she has mastered. This innovation is

intended to better pinpoint students' deficiencies in order to minimize their time in developmental courses. The use of high school grades instead of or in addition to test cut-offs is also gaining traction as a way to more accurately place incoming students. For example, North Carolina's system now waives testing for recent high school graduates with a GPA of 2.6 if they took the prescribed high school math courses, including two years of algebra (Burdman, 2012).

In Florida, recently passed legislation assumes all high school graduates are college-ready in math, effectively eliminating developmental math from the state for large segments of the pre-college population (Burdman, 2013).

Faculty Training

Except for the idea of eliminating developmental education altogether, all of the interventions described above take some level of staff professional development. Many of them require teachers to learn to teach completely differently than they may be accustomed to. Professional development is particularly important for developmental education instructors, as these individuals tend to have limited previous training for teaching developmental math students (Chung and Higbee, 2005). Unfortunately, studies have found that most community colleges provide only episodic staff development activities for these instructors, which tend to take the form of one-day workshops or seminars led by outside experts, or else informal and isolated conversations among colleagues or in departmental meetings that focus on logistics or content knowledge rather than pedagogy (Grubb et al. 2011c; Bickerstaff et al. 2014; Bickerstaff and Cormier, 2015). Developmental and basic skills courses also have high rates of part-time instructors with very limited opportunity for professional development (Gerlaugh, Thompson, Boylan et al., 2007; Washington State Board for Community and Technical Colleges, 2012b).

In a recent case study of 13 community colleges in California, Grubb (2011b) “very rarely saw any group work or student cooperation in trying to understand math issues; in these basic skills classes, students usually have an instructional relationship only with the teacher, not with each other. In conventional terms these are teacher-centered classrooms, not student-centered” (Grubb et al, 2011b). They witnessed no examples of acceleration programs or contextualized math and after quizzing administrators on where it was happening received one email in reply that there was a faculty member at one of the colleges doing contextualized math. Their hypothesis is that, despite positive evaluation results, the practice of contextualization has dwindled since the 1990s when they conducted a similar study of colleges. This is so even though their study selection of 13 colleges was biased to favor more innovative colleges. They noted that the majority of students are taught math courses in isolation with very little consideration of their future career goals, prior knowledge or specific deficits. They also reasoned that, given the high reliance on part-time faculty members at community colleges, it is likely that individual students are exposed to a wide range of pedagogical and content knowledge expertise (Grubb et al, 2011b).

While innovations are clearly happening, most (except in the states noted) are still small-scale and institution specific and few have been rigorously evaluated (Burdman, 2013). No interventions I know of address the high proportion of part-time faculty in these programs despite research showing that high proportions of part-time faculty are detrimental to student outcomes (Jacoby, 2006; Boylan, 2002). Nor do they address recent cuts in funding, the lack of teacher training that developmental educators receive (Zachry-Rutschow and Schneider, 2011), the varied student populations, some with fairly major cognitive difficulties (Grubb et al., 2013), the low pay and stature of developmental educators within institutions, or the low status assigned

to these programs in institutions. Given these unaddressed factors, and despite recent innovation and change efforts, the average community college program still looks much like it did in the 1990's—placement testing, mandatory placement, and mandatory progression through a predefined series of levels. Gaps in the literature still exist around the demographic characteristics of developmental education students in community colleges, the identification of successful programs and institutions, and illumination of what makes some programs or institutions more successful than others. There is also a lack of theory development to support work with such a diverse group of students and institutions.

2.3 Literature Gaps

Current research has largely failed to document, analyze, or classify programmatic approaches to developmental education that might be related to differential student success. This lack of information is due in part to the relatively recent external recognition of low success rates but also is because of the difficulty in accessing reliable information about large numbers of programs, and the range of definitions, student populations, and perceived quickly shifting practices and innovations that developmental education programs encompass. Unfortunately, this lack of a comprehensive picture of developmental education programs has contributed to either the complete elimination of the programs by state level policy actors as unnecessary and perhaps counterproductive, or a focus on faddish approaches with little underlying theory or even agreement about the problem.

Current research attempting to document intervention strategies that may produce improved outcomes has largely met with disappointing results (Zachry-Rustchow & Schneider, 2011). Research has focused largely on two elements of developmental education. The first is the

accuracy and validity of the placement exam itself (Noble, Schiel, & Sawyer, 2004; Hughes & Scott-Clayton, 2010), and the second is the efficacy of a wide range of interventions (Duranczyk, Goff & Opitz, 2006; Hodara, 2011; Wachen, Jenkins, Belfield & Van Noy, 2012; Weissman et. al. 2011). Intervention studies have tended to focus on new programs (e.g. the development of learning communities) in a limited range of settings (i.e. one community college district). Current research tends to be either in an economics (production function) or a student development tradition. The interventions studied have focused on individual students as the problem (e.g. if students are more engaged, they will be more successful) and focus on students or intervention programs as the unit of analysis in isolation rather than on the entire developmental education program or system.

What happens inside the dev ed classrooms and the pedagogical content and strategies of institutions is just as mysterious. Students are taught English or math courses in isolation with very little consideration of their future career goals, prior knowledge or specific deficits. Given the high reliance on part-time faculty members at community colleges particularly in dev ed, it is likely that no uniform curriculum or widely known and adhered to course outcomes exist and that individual students are exposed to a wide variety of pedagogical and content knowledge expertise. While of utmost concern in K-12 education, these instructor preparation and curriculum content questions are mostly unexamined in the pre-college segment of higher education.

Heightening the need to understand program variation is recent legislation in Washington and elsewhere that allocates funding to institutions in part based on student outcomes. In Washington this funding scheme (while still a small but growing percentage of funding overall) awards colleges “points” for moving students through a series of milestones. There are eight

“milestones” measured on the way to a certificate or degree but the ones important for this study include completion of basic skills, completion of developmental education, and completion of a first college-level math course. The State Board for Community Colleges (WASBCTC) monitors student point accumulation and awards small amounts of funding to institutions based on their accumulation of points. However, the WASBCTC has not investigated to what extent student characteristics influence student success outcomes. It may or may not be true that policy and practice variables account for only a small part of the accumulation of points. Investigating institutional variation can help disentangle school effects from the effects of intake characteristics of students who attend a particular community college. Under the Student Achievement Initiative (SAI) pay for performance mechanism, it is imperative that studies of school effects examine the ways that colleges can use policy and practice variables to influence students’ academic performance (Ma & Willms, 2004; Willms, 1992).

In addition, gaps in the literature exist around the demographic characteristics of developmental education students, the empirical identification of successful programs and institutions, an illumination of what makes some programs or institutions more successful than others, and theory development about promising ways to support such a diverse group of students and institutions. As opposed to studies examining particular interventions, this research seeks to discover whether some *programs* are more successful at fostering success in developmental education and what they do differently from others.

Chapter 3

Mixed Methods Research Design

3.1 Research Questions:

This research is centered in 28 Washington State community colleges and examines student outcomes in math developmental education programs. Three main questions are asked.

- 1) To what extent and in what ways do developmental math program elements vary across institutions? Developmental education may vary widely even within one relatively tightly controlled, homogenous state system of community colleges, such as the system in Washington. Programs may have differing course sequencing, intervention strategies and approaches, referral and advancement policies, etc., and this variation has not been fully described in previous research.
- 2) To what extent do student outcomes, as measured by completion of the developmental math sequence, completion of a first college-level math course, and the highest education attainment a student is able to reach, vary across the different math developmental education programs, after controlling for student demographic and academic background characteristics among the 28 community colleges in Washington? What amount of overall variance is contributed by student characteristics vs. programmatic factors? Wide institutional variation has been found in previous outcomes studies of professional-technical programs leading to terminal associate degrees in Washington, suggesting that institutional or programmatic variables may be contributing significantly to student success (Scott-Clayton & Weiss, 2011).

3) What program policies and practices seem to be associated with positive outcomes for developmental education students? Can developmental education programs be categorized in some meaningful way according to their programs and practices? Is there a “typology” or categorization of program approaches that seems to be associated with either positive or negative results? For example, do schools with better (or worse) results share certain programmatic characteristics in terms of policy and practice variables (e.g. method by which students are placed into courses/levels, whether the college offers accelerated pathways, etc.), controlling for student characteristics.

3.2 Conceptual Framework

Attention to process or environment as the link between inputs and outputs in educational settings brought about the input-process-output (IPO) model (Ilgen, Hollenbeck, Johnson, & Jundt, 2004). Purkey and Smith (1983) first adopted the IPO model for school-effects research. Since then the IPO model, and similar variations, has been used in many studies of school effects at the K-12 level (Ma, Ma, & Bradley, 2008). In the IPO model students are seen as bringing into their schools different individual characteristics as well as different cognitive and affective conditions. Schools are viewed as channeling or processing, through different school contexts and climates, students with differing backgrounds into different categories in their schooling outcomes, such as performance (i.e., students in different school contexts and climates demonstrate different patterns of educational attainment). Researchers who use this model carefully control the characteristics that make up student background, examine the distribution of outcomes across students and schools, and identify salient school policy and practice characteristics that may process students into different outcomes (Ma, Ma, & Bradley, 2008). In

higher education, Alexander Astin described a similar model he called the I-E-O (Input-Environment-Outcome) model, stipulating that characteristics college students bring with them (inputs), as well as college experiences and settings (environment), must be considered when accounting for student outcomes (Astin, 1985).

Current research has not examined whether some college environments appear to be more successful at developmental education than others, in part because of the wide range of definitions, policies and practices found in developmental education programs (Bailey, 2009). Rosenbaum, Deil-Amen and Person, (2006) found wide variation in institutional level policy and practice variables among and between community colleges and for-profit institutions of higher education in the Chicago area and similar variation in subsequent student outcomes. They suggest that this institutional variation may be a bigger predictor of student success (or at least one more easily affected by policy levers) than individual student characteristics (Rosenbaum, Deil-Amen & Person, 2006).

Two other studies, by researchers at the Community College Research Center (CCRC), showed similar results. In the first, researchers measured student success by the completion of a 1-year certificate in similar technical programs at community colleges in Washington. They found completion rates ranged from 12% to 66% using extensive control variables and a matching technique to ensure comparability among students across institutions (Scott-Clayton & Weiss, 2010). In a different study of institutional characteristics associated with student success in community colleges, the authors found that larger sized institutions and those with large proportions of part-time faculty, minority students, and money spent on academic support (as opposed to instruction, administration or student services) were negatively associated with student degree completion (Bailey et al, 2005).

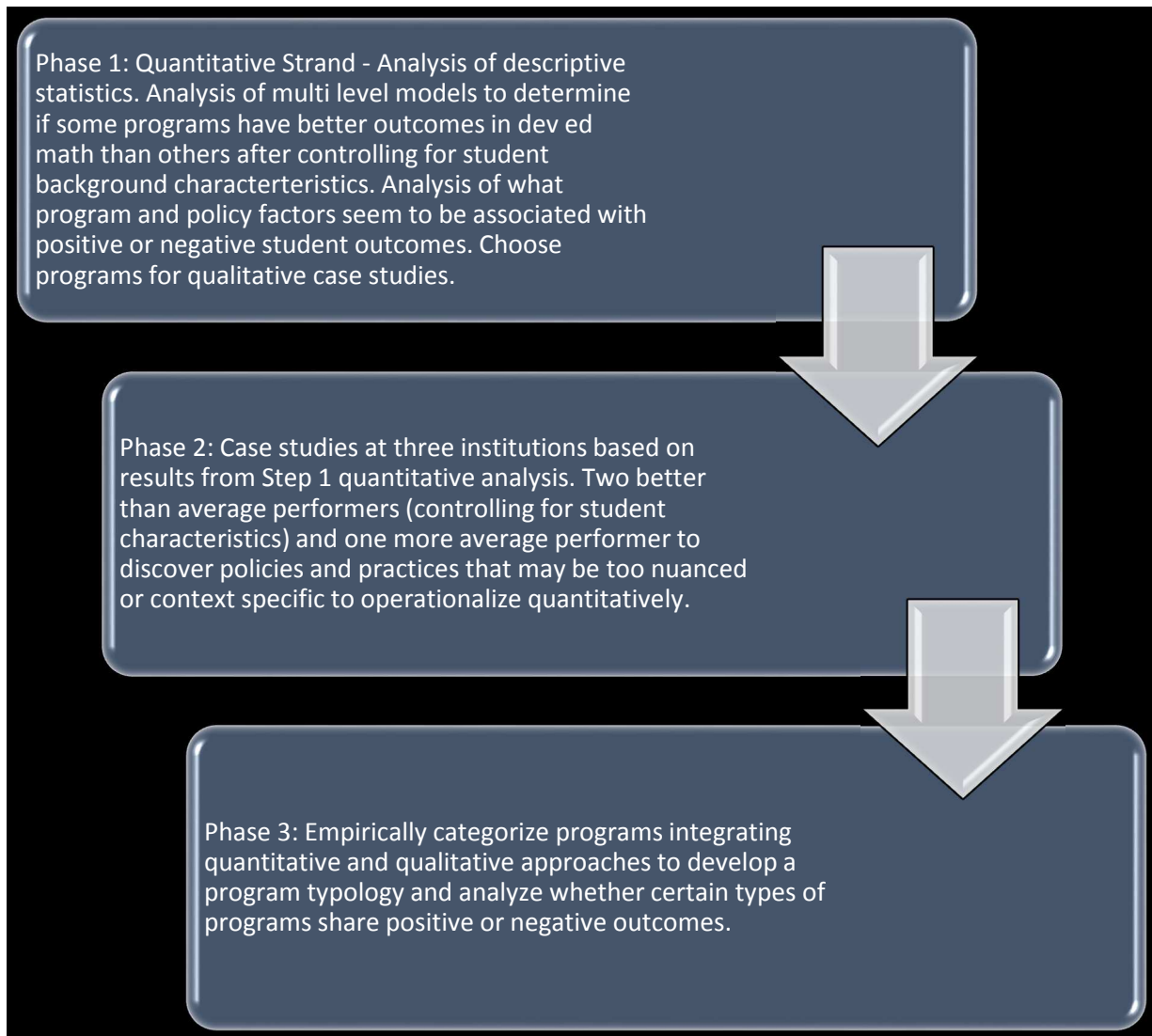
In addition, there appear to be differences in referral to and enrollment rates in developmental education in Washington. Some 53 percent of 2007 high school graduates enrolled at the community and technical colleges in Washington took one or more pre-college courses in their first year of attendance. The rate of pre-college course taking at community colleges ranged from a low of 43 percent at Centralia College to 69 percent at Big Bend Community College, suggesting either fairly large differences in student needs or different assessment policies between institutions (Washington State Board for Community and Technical Colleges, 2010). Analysis of many different types of institutional variation is widely reported in K-12 schools but has not been systematically studied in higher education (Bailey, et. al, 2005).

3.3 Mixed Methods Research Design Overview

To begin to answer these questions I employ a mixed methods, sequential, explanatory study (Ivankova, Creswell & Stick; 2006) that aims to find evidence of programmatic or institutional characteristics, including policy and practice variables, that might be associated with greater student success in developmental math education. The research proceeds in three phases. First, quantitative analysis reveals statistically significant student outcomes differences between programs (after controlling for student background characteristics), and this analysis is used to rank high, average, and low performing colleges. Qualitative case study research then attempts to fill in quantitative findings with rich descriptions in three colleges, two high performers and one more average performer (controlling for student characteristics), to understand program policies and practices “on the ground” from the perspective of administrators, faculty members, and students. The third phase brings the quantitative and qualitative phases together to attempt to categorize programs according to their observed policies and practices in a meaningful way that connects to student outcomes.

Due to their potential for utilizing “complementary strengths and non-overlapping weaknesses” of quantitative and qualitative research approaches (Tashakkori and Teddlie, 2003, p. 299), mixed methods research designs can offer greater capacity to increase “legitimatization” and minimize validity threats in research (Onwuegbuzie, Johnson and Collins, 2011). In this case, neither quantitative nor qualitative methods alone are sufficient to answer the research questions around program variability in policy and practices related to student outcomes. The idea is that the qualitative research allows a fuller picture to be created of developmental education programs and their program and policy differences that might be associated with student outcomes. It helps fill in gaps in order to offer a more detailed and holistic picture than the quantitative research alone could provide.

Figure 1. Research Design Overview



3.4 Quantitative Strand Methodology

The data for the quantitative portion of the research was drawn from an existing dataset collected by the State Board for Community and Technical Colleges (WASBCTC) as part of its Student Achievement Initiative (SAI). This unique dataset includes 16,877 students and

represents every developmental math student enrolled in a low level of developmental math (i.e. those who have to pass from two to four dev ed courses to reach the college-level) in Fall 2011. In the dataset only low-level developmental math education students were chosen in order to ensure that students in the sample have enough exposure to the “treatment” of developmental math programs for meaningful analysis in relation to outcomes. While this reduces the sample somewhat, the tradeoff is worth it to achieve a population of students who have significant achievement deficits in math and have not simply been misplaced by assessment tests.⁷

Student success rates (controlling for student background demographic and academic background characteristics) were measured on three outcome variables (described in detail later) at each of the 28 community colleges. Based on these results, two above average performing colleges and one more average college performer were chosen on which to pursue case studies. The case studies are designed to investigate further what colleges are doing on the ground in their developmental math programs and to gain a fuller and more nuanced picture of program and policy variables that are difficult to capture in quantitative data alone.

Appropriateness of Hierarchical Linear Modeling and Hierarchical Generalized Linear Modeling

Multi-level modeling is necessary for this analysis because of the nested structure of the data. Since differences in student characteristics nested within institutions presumably matter to student success outcomes for community college students, multi-level modeling is an appropriate methodology, and has not been used in prior analyses with this dataset. Multi-level analysis of WASBCTC data expands upon prior research, and also uses variables shown to be significant in

⁷ As suggested in the previous chapter, studies have called into question the placement accuracy and validity of the COMPASS and/or Accuplacer tests commonly used for assessing math ability at community colleges. See Scott-Clayton (2012); Belfield & Crosta (2012); Hughes & Scott-Clayton (2011).

previous research (see Table 1). Multi-level modeling is also appropriate to handle unbalanced data where the number of students within colleges varies (Raudenbush & Bryk, 2002), as is the case with this dataset. In the calculations of the probabilities of the outcome variables, institutions with more students are given more weight, and those with few students get less weight. Multilevel estimation directly incorporates the clustered (here by college) sample design into analytic models and reduces parameter uncertainty by combining maximum likelihood techniques with empirical Bayes calculations (Raudenbush & Bryk, 2002).

Description of student data

The 16,877 students included in the analysis were enrolled in levels 1, 2, or 3 of developmental math in fall 2011 and were nested within the 28 community colleges in Washington.⁸ The smallest developmental math program in the sample has just over 200 students while the largest program has nearly 2,000 students, with the majority of programs clustering in the 600 to 800-student range. The dataset contains six demographic and academic characteristics of students. Variables include the level of developmental education the student was enrolled in, whether the student was an underrepresented minority (URM)⁹, age, a measure of SES based on

⁸ Level of developmental math is standardized by WASBCTC researchers to make comparisons across institutions possible. A 1-4 scale is used with 1 being the lowest level of math education offered and 4 the level before college-level. Level 1 = four levels below college-level math, or lowest level available at the college involving algebra; 2 = three levels below college-level math; 3 = two levels below college-level math; 4 = one level below college-level math. Level 4 students were excluded in the analysis as described earlier

⁹ URM students are defined here as African-American, Latino, and Native American students. The categories were created by this researcher from existing data where six categories of race were present. The WASBCTC does not report underrepresented minorities but instead reports all “students of color.” The system reports that about 24% of all community college students in Washington are unrepresented minority students.

census categories of self-reported household income¹⁰, and self-reported prior education.¹¹ The dataset also includes three outcome variables (described in detail below) as of spring quarter 2014. The current dataset contains three years of data for the fall 2011 entry cohort, which is a reasonable amount of time to expect for the outcomes in question to be able to develop.

Table 1. Student Variables in Multi-level model

Student Level (Level 1) Variables	Theory/Hypothesis with Literature	Data Source
Level of entering developmental math in Fall 2011 as standardized by WASBCTC (1=4 levels below college level; 2=3 levels below college level; 3=2 levels below college level)	Students assigned to lower entering levels of developmental math have lower chances of completing the developmental education sequence and going on to certificate or degree completion (Bailey, Jeong, & Cho, 2010)	WASBCTC
Birth Year/Age	Older students are less likely to progress through the developmental sequence (Bailey, Jeong, & Cho, 2010)	WASBCTC
Race/Ethnicity (Underrepresented minority students =1, non-underrepresented minority students =0)	Higher percentages of Black and Hispanic undergraduate students (45% and 43%, respectively) than Asian students (38%) or whites (31%) reported that they had ever taken a remedial course (Aud et al., 2011). African American students are less likely to progress through their full remedial sequences (Bailey, Jeong & Cho, 2010).	WASBCTC
Prior education (6 categories, 1=< 9 th grade; 2=< high school; 3= GED or high school 4=some college;	While not controlled for in previous studies, the hypothesis here is that students with more prior education will be more successful.	WASBCTC data from self-reports

¹⁰ Five categories from census definitions are used based upon self-reported household income quartiles in current dollars in 2011, 1=<27k (19.0% of respondents); 2=27-50k (19.7%); 3=50-76k (19.2%); 4=76-119k (17.6%); 5=119k+ (10.8%); When the student did not self-report this variable it was imputed from whether they received a Pell grant using the expectation maximization technique (Tabachnick & Fidell, 2007).. Pell grants are federal grants given to low income students who qualify. There is no household income threshold for receipt of a Pell grant. Instead eligibility is determined by a formula that takes into account parental income and assets (or student income and assets if the student is independent), household size, the number of family members attending college, and other factors such as parent age. The vast majority of students eligible for a Pell grant come from households where income is less than \$60,000 per annum (pellgranteligibility.org)

¹¹ Six categories of self-reported prior education have been developed by WASBCTC staff: 1 =< 9th grade (13 students); 2= < high school (10.2%); 3=high school or GED (61.4%); 4=some college (18.5%); 5=A.A. degree (1.6%); 6=B.A. or higher (.9%)

5=AA degree; 6=BA or higher)		
SES (A self-reported measure of household income, five point scale: 1=lowest, 5=highest)	Hypothesis is that students with higher household incomes are more successful.	WASBCTC data from self-reports
Institution attended (Level 2 ID match variable)		WASBCTC

The mean age of students in the dataset is 25.54 years, The WASBCTC reports the average age system-wide of all community college students in Washington is 26 (WASBCTC, 2014). In the dataset, 22% of the students were underrepresented minorities and 50% received a Pell Grant in fall quarter 2011. Statewide about 24% of all community college students are underrepresented minorities and about 43% receive a Pell Grant (WASBCTC, 2014).

Table 2. Descriptive Statistics of Student-Level Variables

<i>Variable</i>	<i>N</i>	<i>Mean</i>	<i>SD</i>	<i>Min</i>	<i>Max</i>
Age	18872	25.54	9.25	14	84
Underrepresented Minority	18171	.22	.41	0=Not URM	1=URM
SES	16317	2.75	1.32	1	5
Prior Education	17504	3.15	.65	1	6
Pell recipient	18878	.5	.5	0=No Pell	1=Pell

Missing Data

Overall there is a small amount of missing data in the dataset. The largest amount of missing data is the self-reported SES category where 14.6% of students did not report their household income. To address this relatively large amount of missing data, I imputed SES for the missing students from the nearly complete variable of whether the student was eligible for a Pell grant using the expectation maximization technique. In addition, 7% of students did not report their prior education while less than 4% of data is missing in the underrepresented minority field. Less than 1% of data is missing in regard to both age and whether the student received a Pell

grant. In multilevel regression the default approach for handling missing data at level 1 is listwise deletion of the individual for variables missing (Little & Rubin, 2002; Enders, 2010) and that is the technique used here. Listwise deletion resulted in the dataset being reduced from 18,878 students to an analytical cohort of 16,877, after imputing missing SES data from Pell grant recipient status. At level 2 (college program and policy variables), all variables must be entirely complete, as is the case in this dataset.

Description of level 2 variables

At level 2, the developmental math program level, the dataset contains a number of program and policy (i.e. alternative placement options, number of levels of developmental math) factors that might be important to student success. Data was gathered from college websites and in some cases by reaching out to state level or college personnel when website information was unclear or unavailable.

Table 3. Program Variables in Multi-Level Model¹²

<i>Variable</i>	<i>Definition</i>	<i>Theory/Hypothesis</i>	<i>Data Source</i>
Student to Faculty Ratio	Student to Faculty Ratio in developmental math courses	While results are mixed, in K-12 large class-size reductions have significant long-term effects on student achievement that are largest for students from less advantaged family backgrounds (Chingos and Whitehurst, 2011). In higher education, studies are typically institution specific and not peer reviewed but find large class sizes reduce student: faculty interaction, lower levels of learning and grades, reduce overall student satisfaction with the learning	WASBCTC

¹² To see an inventory of each program variable by college, see the appendix

		experience, and lower student evaluations of course instruction (Cuseo, 2007).	
Number of levels of developmental math	Number of courses a student starting at the lowest level of college-defined dev ed needs to pass to enter college-level. College-level is defined here as Math 107, a class offered at every community college	Researchers have suggested that a simple reduction in the number of levels of developmental education might be beneficial to student success (Zachry-Rutschow and Schneider, 2011).	Individual Institutions
Use of modules/self-paced courses	Individualized instruction, variable credit (Zachry-Rutschow and Schnieder, 2011) – in practice in WA community colleges these courses are almost always computer aided and take place in math lab settings where the instructor may roam the room helping with individual instruction when necessary (1=yes, 0=no)	Associated with higher pass rate in college-level courses; faster progress through developmental course sequence (Bassett 2009; Bragg and Barnett 2009; Epper and Baker 2009)	Individual Institutions
Differentiated tracks ¹³	Course restructuring through curriculum redesign (Edgecombe, 2010); in practice in Washington colleges often have one pre-college track for students pursuing a STEM (and sometimes business) degree, or a degree at the University of Washington ¹⁴ and one or more additional tracks for students pursuing other	Researchers recommend faster entry into coherent programs of study (Jenkins & Weiss, 2011) and these types of models are associated with higher pass rates for the developmental sequence and similar rates of success (to students who were not in an accelerated pathway) once at the college level (Edgecombe, 2011).	Individual Institutions

¹³ Differentiated tracks aim to align math coursework with a student’s degree program and career ambitions. Often in colleges that have differentiated tracks there exists a pre-college algebra track for students interested in pursuing STEM careers and a more basic math pre-college track, which might include some statistics instruction for students interested in pursuing non-STEM degrees. Differentiated tracks grow out of the call to make math more relevant to students’ lives.

¹⁴ The University of Washington, Seattle, requires completion of an intermediate algebra course for admission for all students, regardless of degree intent, meaning students who wish to transfer to UW-Seattle need to go through the “STEM” track, which includes intermediate algebra.

	degree types. (1=yes, 0=no)		
Assessment preparation course	College offers an on-line or in person course that offers instruction on topics covered in the placement exam to students before they take the exam. (1=yes, 0=no)	No rigorous research tests the efficacy of assessment preparation courses but researchers have suggested that at least some students placed into developmental education may simply need a brush-up on their skills before testing (Belfield and Crosta, 2012; Scott-Clayton, 2012)	Individual Institutions
Statway curriculum	Developed by the Carnegie Foundation for the Advancement of Teaching, Statway is an alternative pathway through dev ed math. focusing on statistics, data analysis, and causal reasoning. Taught using common curricula, assessments, and online platform. (1=College offers Statway; 0=not offered)	No rigorous studies evaluate the effectiveness of Statway. Descriptive and qualitative data from the Carnegie Foundation shows improvement in student persistence (Van Campen, Sowers, and Stother, 2013) and high returns on investment (Johnstone, 2013).	Individual Institutions
College mission statement reflects developmental education	Mission statement or accreditation core themes ¹⁵ contain the words “developmental education” “pre-college education” or “adult basic education” (1=yes, 0=no)	Best practice identified by Boylan (2002), Schwartz & Jenkins (2007), Center for Student Success – California Basic Skills Initiative (2007), Sperling (2009)	Individual Institutions
Mandatory college orientation	New students, including those in dev ed, are required to attend an orientation session before matriculating (1=yes, 0=no)	RCT trials at 8 colleges in Texas showed the programs had a positive impact on introductory college-level course completion in math and writing in the year and a half following the orientation.	

¹⁵ Each college in the study is a member of the Northwest Commission on Colleges and Universities, the accrediting body for the Northwest region. This commission requires colleges to develop “core themes” for each college. The core themes “individually manifest essential elements of its mission and collectively encompass its mission” (NWCCU, 2010).

		(Barnett et al. 2012). A mixed methods study in California community colleges found a statistically significant difference in rate of persistence from the fall to spring among First-Year Experience students as compared to non-participants, especially Latino students (Barnes and Piland, 2011).	
College level faculty also teach dev ed	At least two college level faculty members at the institution taught at least one developmental education course and one college level math course during Spring 2014 (1=yes, 0=no)	Little research explores this topic but my hypothesis is that programs with instructors who teach math at all levels will have a more coordinated curriculum and holistic view of the spectrum of math skills taught, leading to better student outcomes.	Individual Institutions
Achieving the Dream participation	College participates in the national Achieving the Dream Initiative (1=yes, 0=no)	An MDRC report found that average institution-wide student outcome trends remained relatively stable for 26 ATD “round one” colleges over a five year time period (Mayer, et.al. 2014). Another MDRC report found that 3/4 of participating institutions reported what they perceived to be many important environmental changes that supported building a culture of evidence at the colleges (Zachry-Rutschow, et.al. 2011) and that individual colleges spent an average of \$6.3 million on their broad institutional reform process over five years (Zachry & Coghlan, 2010).	Achieving the Dream
Alternative to standardized testing placement option	College does not rely solely on COMPASS or Accuplacer but also uses high school transcripts and/or ACT/SAT scores	High school transcript information – including GPA, math grades and standardized test scores increase accuracy and validity of placement into	Individual Institutions

	and/or college specific faculty developed assessment for math placement (1=yes, 0=no)	developmental or college-level math courses (Belfield & Crosta, 2012; Brown & Niemi, 2007)	
Contextualized Instruction	College offers pathway to integrate developmental math curriculum with professional/technical degree programs where developmental math is taught in the context of a professional technical program with two (or more) instructors integrating curriculum (1=yes, 0=no)	In a literature review of evidence reporting efficacy of contextualized instruction programs, Perin (2011) found that “contextualization seems to be a promising direction for accelerating the progress of academically underprepared college students . . . practitioners who use it observe positive results and the available quantitative evidence indicates that it has the potential to increase achievement.”	WASBCTC

Outcome Measures

Hierarchical Generalized Linear Modeling (HGLM) was employed here to estimate the effects of student characteristics, and community college programmatic context, program and policy variables on the outcomes of: 1) completing the math developmental education sequence within the three year period covered by the data (as a binary yes=1, no=0 variable); and 2) completing a first college-level math course (as a binary yes=1, no=0 variable). Hierarchical Linear Modeling (HLM) is used for the continuous outcome variable: 3) the highest level of educational attainment achieved (interval points 0-8, e.g. 4 points = student completed between 15 and 29 college level credits).HLM (as opposed to HGLM) is used for this variable because of the metrical nature of the variable.

Outcome Variables:

1. Student passed pre-college math sequence (1=yes, 0=no) by spring 2014
2. Student passed at least one college-level math course (1=yes, 0=no) by spring 2014

3. Highest momentum point earned (term defined later) by student by spring 2014, variable assumed to be metrical on a nine-point scale.

Looking at three different outcome variables allows me to examine whether some institutions are excelling at one outcome, for example, accelerating students through developmental education, but perhaps leaving students underprepared for college-level work as reflected in college level math credits attained or highest momentum point earned.

The first outcome variable is a dichotomous measure of whether the student passed the college's entire sequence of pre-college math courses or not. Initial analysis showed that less than half of the students (42%) in the sample passed the precollege math sequence within the three-year period. The second outcome variable is also a dichotomous measure of whether the student passed (with a C or better) at least one college-level math class. Initial analysis shows that 32% of the students have passed a college-level math course. In addition, 29% of the students in the dataset were still enrolled in community college in spring 2014, three years after the start of the data.

Student Outcome #3, Highest Momentum Point Earned

The third outcome variable examines the highest level of education the students attained as measured by "momentum points." Momentum points are used by the WASBCTC to award colleges points that equate to small funding increases. The concept of momentum points and their exact measurements come from what is known as the "Tipping Point" research (Prince & Jenkins, 2005). In a longitudinal study, David Prince of the WASBCTC and Davis Jenkins of the Community College Research Center (CCRC) used transcript data on individual students collected by the WASBCTC to track the academic progress over five years of a cohort of Washington State Community and Technical College students 25 or older who entered the system in 1995-96 with at most a high school diploma. One of the main findings of the study

was that students in the cohort who took at least one year's worth of college credit courses (equivalent to three quarters or two semesters of full-time study) and attained a certificate or other credential over the five years tracked earned substantially more in the labor market than students who did not reach that threshold (Prince & Jenkins, 2005). The researchers concluded that 45 credits and a certificate or degree was the "tipping point" that was substantially rewarded in the labor market.

Based on these findings and other follow-up research tracking two additional cohorts of students and finding additional labor market benefits from attaining at least a 45 (quarter) credit degree or certificate (Prince & Jenkins, 2005), the WASBCTC began developing the Student Achievement Initiative (SAI) in 2006. This program awards colleges a point each time an individual student hits a new benchmark achievement level such as completing the developmental English sequence or passing a college level math class. Initially there were six possible points a student could earn on the way to the "tipping point." In 2012 the point system was revised somewhat and now eight points are possible. Each point equates to a small amount of funding for the institution.

The theory of action in play in the SAI and many other pay for performance schemes that have recently gained popularity nationwide¹⁶ is that models that award funding based on student achievement would encourage colleges to become more efficient and effective in delivering educational opportunities (Hillman, Kelchen and Goldrick-Rab, 2013). In Washington, each recognized momentum point has been chosen because researchers have found that that milestone increases the probability of a student reaching the 45 credit certificate or degree level

¹⁶ In 2013, 16 states had some sort of pay for performance mechanism built into their state higher education budgets where colleges are awarded some funding based on student achievement [or other outcomes?], versus college enrollment alone (Hillman, Kelchen, and Goldrick-Rab, 2013).

(WASBCTC, undated), now known as the Completion Point. The current definitions and associated values are shown below.

Table 4. Momentum Points Definitions

8	Student earned the Completion Point (at least a 45 credit certificate or degree)
7	Student passed a college level math course but earned no certificate ¹⁷ or degree
6	Student earned 45 college level credits but did not pass a college level math course and earned no certificate or degree
5	Student earned between 30 and 45 college level credits
4	Student earned between 15 and 29 college level credits
3	Student passed developmental math but earned < 15 college-level credits
2	Student passed developmental English but earned < 15 college level credits
1	Student earned Basic Skills gains ¹⁸ , but no other momentum gains
0	Student made no momentum gains

The WASBCTC disburses funding based on point measures in three ways. The first is from a baseline measure of where the college performed in the previous academic year. Points (equated with dollars) are awarded when a college moves up in net points (aggregated over all students) from the previous academic year. Of the total dollars available under SAI, 45% are awarded for net point gains. In addition, to mitigate penalizing of institutions for enrollment drops that might affect net point gain, a points per student measure awards funding (45% of the total available) for gains in points per FTE student. Finally a separate completion measure awards 10% of overall funding specifically for the award of certificates or degrees. (WASBCTC, undated).

¹⁷ Certificate must be at least 45 credits.

¹⁸ Earned when a student moves from Basic Skills level courses to the (higher) developmental education level.

Multilevel analysis can play an important role in improving the Student Achievement Initiative because it can help disentangle college effects, which are what is intended to be rewarded in the regime, from the effects of intake characteristics of students who attend a particular community college. At this time the state board does not account for student characteristics in assessing colleges' points accumulation, meaning that some schools might be more likely to accumulate points simply based on student characteristics rather than institutional policy or program factors.

In addition, measurable institutional climate effects that relate to outcomes may indicate direct ways of reforming school policies and practices to improve student performance. In the ever-growing system of educational accountability, it is imperative that studies of school effects examine the way that colleges can use policy and practice variables to influence students' academic performance (Ma & Willms, 2004; Willms, 1992).

HGLM and HLM Analysis

Data is analyzed in HLM 7.01, the latest version of the software available. The first step in this process is to estimate the grand mean of math achievement over the sample with adjustment for clustering of students within colleges and for different sample sizes across schools. This is done by testing the null model, in this case: $Y_{ij} = \gamma_{00} + r_{ij} + u_{0j}$. The null model estimates variance components at the student and college levels. Because of the data hierarchy, the null model decomposes the total variance in math scores into variance attributable to students within programs and variance attributable to programs. The latter is a good indicator of the existence of program effects where statistically significant between-program variance exists in program average math scores (i.e. intraclass correlation). The proportion of variance at the program level ranges from 0 to 1 in magnitude, with higher proportions indicating larger

between-school variance. Finally, this null model will be used as the baseline model to compare with the results of more elaborate analytic models (Raudenbush and Bryk, 2002).

The next model specified is the student model of program effects. The student background characteristics controlled for in this model are, initially: student's entering developmental education level, age, underrepresented minority status, prior education, and SES. These are the student control, or level 1, variables in the HLM model. Under this model, student level variables are assumed to have the same slopes or fixed effects across all colleges. Ma, Ma and Bradley (2008) "caution against specifying random effects unless estimating the variability in the effect of individual differences across schools is the primary research question." Thum and Bryk (1997) similarly state that, "either all coefficients should be fixed or the random slopes should be objects of study" (p. 105).

In this research all student-level variables are treated as fixed effects. Such a treatment is appropriate if random effects are not a part of the research questions (Raudenbush & Bryk, 2002). Because this analysis aims to identify program-level variables that are responsible for variation in math achievement among programs without any attempt to investigate, for example, within-school SES or other student-level variable differences in math achievement across schools, (Ma, Ma & Bradley, 2008). The research questions are not interested in variation across individuals or slope differences across schools so a fixed effects model at level one is appropriate. At level two, program level variables are again treated as fixed and centered around their grand mean as the research is not interested in examining, for example, within-school socioeconomic or other similar variables in educational outcomes (Ma, Ma, and Bradley, 2008).

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¹⁹ Specific statistical models are presented in the next chapter.

Residual files were examined to look at results by program. Residual files of each outcome variable reveal the highest and lowest Empirical Bayes (EB) and Ordinary Least Squares (OLS) estimates of adjusted mean for b , representing the intercept for each program on each of the three outcome variables. Using both the OLS and EB estimates, programs were sorted into high, average, and low performers for each of the three outcomes based on the intercepts. A comparison between program rank using EB versus OLS revealed that while some individual programs switched order the overall program rank category (high, average, or low) did not change from the EB to OLS estimates. Results of this analysis were used to choose programs for further qualitative study, as described below.

Program Categorization

After analyzing individual variables and their association with student outcomes, I move on to examine whether certain types of programs share positive or negative outcomes. Zumeta (1996) used a similar technique in a paper linking state policies to enrollment growth in private non-profit higher education. He surveyed state policy actors on a number of dimensions to determine whether states shared recognizable policy approaches and used cluster analysis to categorize states into what he called *policy postures* regarding the state stance toward private non-profit higher education. In 2012 I worked with Dr. Zumeta and Dr. Robin LaSota to use this same methodology to begin to categorize state policy postures toward for-profit institutions of higher education (Meza-Apple, Zumeta, & LaSota, 2012). Using secondary data I constructed a dataset that described variation in state policies in this sphere. I use this same methodology here, constructing a descriptive dataset (the same Level 2 dataset described earlier) and seeking to categorize institutions into typologies or postures that might be empirically linked to student outcomes through Principal Component Analysis (PCA). (See appendix for a spreadsheet of

program policies by institution)

In PCA, variables that are correlated with one another but largely independent of other subsets of variables are combined into components (Tabachnik and Fidell, 2007). The specific goal of PCA is to summarize patterns of correlations among observed variables, to reduce a large number of observed variables to a smaller number of factors in order to provide an operational definition (a regression equation) for an underlying process by using observed variables (Tabachnik and Fidell, 2007). The first principal component has the largest possible variance—that is, accounts for as much of the variability in the data as possible—and each succeeding component in turn has the highest variance possible under the constraint that it is orthogonal (i.e., uncorrelated with) the preceding components. The principal components are orthogonal because they are the eigenvectors of the covariance matrix, which is symmetric (Jolliffe, 2002).

A major constraint on a reliable PCA analysis here is the small sample size of 28 colleges. This problem can be somewhat mitigated if there are strong correlations and a few distinct factors. In my dataset, the college data is complete with no missing values. The original dataset contains 12 program and policy variables, which were further consolidated because of their theoretical similarities, into five variables for use in the PCA²⁰.

The PCA analysis first uses principal component extraction and varimax rotation. From the results the factorability of the correlation matrix is estimated, the rank of the observed correlation matrix is determined, and the likely number of factors and the variables that might be excluded from subsequent analysis are analyzed. In this way it is hoped that some meaningful

²⁰ See the 12 original variables in Table 10 on page 84, “Level-2 independent variables.” The five transformed variables can be seen in Table 17 on page 103.

and theoretically consistent organization of variables into policy postures or categorizations can be made that empirically links student outcomes with program policy and practice features. PCA generates scores for each college on the two components. These scores are then used as predictor variables with the outcomes described earlier in a standard logistic regression to determine whether the scores on each component are significantly related to the outcomes in question. In essence, the components are certain sets of policies and practices (analogous to Zumeta's policy postures) associated with the math student outcomes. Results from this analysis of college typologies was used to inform qualitative research findings, as described below.

3.5 Qualitative Strand Methodology

While the statistical analysis described so far is no doubt valuable, it still does not address a gap in the literature regarding the lack of thick qualitative description of institutional and programmatic differences that may simply not be represented or be too nuanced or varied even within the institution to capture through quantitative data alone. The qualitative phase employs case studies of two better than average performing community colleges and one average performer—after differences in student characteristics are accounted for—with respect to developmental education outcomes as measured in the quantitative phase of the research. Merriam (2009, p. 38) defines case studies as, “In-depth analysis of a bounded system.” Case studies involve purposeful sampling and data collection via interviews, observations and document analysis. In case studies data analysis is inductive and comparative and the focus is on making meaning and understanding. “To that end, findings seek to be richly descriptive and presented as themes or categories” (Merriam, 2009, p. 39).

The purpose of the case study phase of the research is to examine how developmental math education is carried out on the ground in the three programs under study *and* to gain a better understanding of the policies and practices that may promote student success in developmental math programs from the perspectives of administrators, faculty members and students who have valuable experience in these programs. Ultimately, the goal of the research is to discover promising interventions in improving community college students' progression through the developmental math sequence and to uncover nuances or environmental factors that may be important for student success and may not have been described in quantitative research alone. To that end the qualitative strand seeks to answer several questions including:

1) What are community college students, faculty members, and administrators' perspectives about what enhances or deters progression in developmental math sequences? 2) To what extent are literature-identified best practices in play at the case study institutions? 3) How is developmental math defined, organized in terms of course structure, delivered in terms of technology, and supported in terms of resources at the community colleges under study? 4) To what extent are traditional models vs. new intervention approaches, such as those described earlier, being experimented with at the colleges under study and which such interventions are in place?

Understanding the state context

Before I began the in-depth case studies, two individuals from the staff of the State Board for Community and Technical Colleges who are very knowledgeable about developmental math programs statewide and have a wide-angle view of program variation across the system were interviewed. These interviewees from state policy offices were selected because they have a central role by virtue of their role position in implementing, designing, and/or evaluating policies

or programs intended to strengthen students' success in developmental math (Patton, 2002). From these interviews I sought an overview of current reforms, innovations, and the rate of adoption or uptake of reforms among community colleges across the state to give a good contextual understanding of current policy and practice statewide. The interviews focused on the respondents' perception of variation among developmental education programs in general, variation in innovations across the state, and state policy context, data collection at the state and institutional level, as well as exploring what mechanisms or policy levers they find important for strengthening student outcomes. Information on state policy context serves as a backdrop to understanding state influences affecting the selected community colleges' institutional capacity and effectiveness in improving developmental education math completion rates.²¹

Case Studies in Three Community Colleges

Case study methods are especially appropriate for intensive, in-depth examination of complex phenomena, such as the connections between educational policies enacted across multiple arenas and the instructional practices of individual schools and teachers (LeCompte & Preissle, 1993; Merriam, 2009). Below I describe the rationale that was used to sample the three community colleges, my data collection activities, and the methods that I employed for data analysis.

In this research case studies include interviews with program administrators and faculty in the three institutions. At two of the colleges I was also able to interview students. Unfortunately, at the third college I was unable to gain access to students because of institutional concerns about the lack of a human subjects research process for the campus which was being developed but not in place when I conducted my research. At one of the two colleges where I

²¹ Interview protocols are included in the appendix.

was able to interview students, interviews were conducted in a focus group while in the other case individual interviews with students were held. In addition, I was able to observe two developmental math classes at the two colleges where interaction with students was allowed. Qualitative analysis also includes document review, primarily of the college math department and advising websites, to discover math course sequencing, assessment policy, and any math instructional innovations noted. For example, one of the top performing programs participating in the case studies is offering Statway courses even though only two other colleges in the population of 28 colleges under study offer this option. Website and document review allows for contextual background insights to be applied while the researcher is conducting interviews and asking questions related to why and how an intervention or other practice or policy was chosen and implemented and its perceived success.

Several qualitative studies have suggested programmatic variables of importance to student success and I ask about these in my qualitative inquiry. In 2002, Boylan surveyed 36 colleges with reputations for strong developmental education programs and, based on surveys and student outcome data, he chose five “highly effective” programs and conducted follow-up interviews. He then used the findings to inform the creation of a best practices guide (Boylan, 2002). In 2007, the Center for Student Success reviewed literature related to basic skills and developmental education, including in their review 250 articles published over a 30-year time frame. Most of the articles were small, individual college reports and less than half appeared in peer reviewed journals (Center for Student Success, 2007). Also, in 2009, Sperling surveyed Massachusetts community college administrators, interviewed administrators, faculty chairs and program coordinators, and compared practices he found with those covered in his literature review of research-based best practices and policies (Sperling, 2009). Finally, Schwartz and

Jenkins (2007) conducted a literature review of effective practices but noted that the majority of analyses are not rigorous studies. Since that time a number of studies have focused on individual promising practices and noted a number of innovative developmental education practices, including contextualized learning and acceleration models. The studies noted above describe the following “best practices” that I looked for in case study visits.

Table 5. Best Practices for Developmental Math Programs

Management and Administration	
Ongoing evaluations are conducted of programs and policies; programs and policies are revised as needed	Best practice identified by Boylan (2002), Schwartz & Jenkins (2007), Sperling (2009), Center for Student Success (2007)
Collaboration between support services staff and faculty/academics	Boylan (2002), Center for Student Success (2007), Grubb (2001)
Orientation for new dev ed faculty	Boylan (2002), Center for Student Success – California Basic Skills Initiative (2007), Sperling (2009)
Ongoing teacher professional development offered and widely used	Boylan (2002), Schwartz & Jenkins (2007), Center for Student Success – California Basic Skills Initiative (2007), Sperling (2009)
Curriculum/Pedagogy	
Curriculum alignment between developmental education and college level courses	Boylan (2002), Schwartz & Jenkins (2007), Center for Student Success – California Basic Skills Initiative (2007), Sperling (2009)
Self-directed learning/self-monitoring/teaching of study skills	Boylan (2002), Schwartz & Jenkins (2007), Center for Student Success – California Basic Skills Initiative (2007), Sperling (2009)
Employ varied instructional methods to accommodate diverse learning styles	Boylan (2002), Center for Student Success (2007)
Active learning strategies employed, including collaborative learning	Boylan (2002), Schwartz & Jenkins (2007)
Teaching tailored for adult learning	Schwartz & Jenkins (2007)
Support Services	
Comprehensive support services offered on campus which are tailored to students' needs and generally linked to dev ed program	Boylan (2002), Schwartz & Jenkins (2007), Sperling (2009)

Attention is paid to the social, emotional, and cognitive development of the student (holistic approach)	Boylan (2002), Schwartz & Jenkins (2007), Center for Student Success – California Basic Skills Initiative (2007)
Proactive and frequent counseling/advising provided	Boylan (2002), Schwartz & Jenkins (2007), Sperling (2009)
Tutoring or external labs provided for extra support	Boylan (2002)
Training provided to tutors	Boylan (2002)
Faculty	
Adjunct faculty are integrated within college community and dev ed practice	Boylan (2002), Schwartz & Jenkins (2007), Sperling (2009)
Collaboration among faculty	Boylan (2002), Schwartz & Jenkins (2007)
Peer review/coaching of teaching	Boylan (2002), Schwartz & Jenkins (2007)

While these practices have been identified in “best practice” research, many of them are quite general and there are no doubt others that might be important. For example, absent in these practices is much information on faculty culture, employment policies (e.g. full-time vs. part-time, security of employment) for faculty or data collection and use. The qualitative research here focuses not only upon identified best practices but also seeks to uncover information that has not been identified in previous research, such as systematic data use to improve programs and services and/or to guide existing or new resource allocation; centrality of developmental education to institutional rhetoric and mission; commonly used curriculum and pedagogy in classrooms; use of technology and any other interventions meant to boost developmental education performance as described by program participants.

Sampling

In order to choose the three colleges where case studies were performed criterion sampling was employed. Criterion sampling involves selecting cases that meet some predetermined criterion of importance (Patton, 2002, p. 238). The main criteria were to have two

high performers and one more average performer (net of student characteristics) and then to have a diversity of student populations based on theorizing that programs with different types of students might display unique and diverse interventions and therefore the most program variation. To choose institutions for qualitative study, colleges were first divided into high, average, or below average performers on each of the three outcome variables as described earlier using the residual files generated in the HLM and HGLM analysis. Colleges in the “high” category ranked in the top 1/3 of performers, average performers in the middle 1/3, and below average performers in the bottom 1/3 for each of the three outcome variables. Next, a list was generated of colleges in the above average category for each outcome variable. Therefore, each variable produced a list of nine (of the total 28) above average performers. Six colleges appeared on the list of high performers for each of the three outcome variables, indicating that high performance is somewhat uniform across these outcome variables. This list of six consistently high performers comprised the schools considered for inclusion in case studies for the two available slots for such performers.

The second criterion considered was diversity of students in the programs. The two programs chosen have student populations in developmental education that differ from each other in terms of age, race/ethnicity, and income level. Finally, these two programs are also different in terms of the types of students they attract. The first (College D) is primarily a transfer-oriented institution in a mid-sized city surrounded by a rural area, with a relatively large math developmental education population of about 800 students in the sample. The other (College AA) is in an urban center with a student population more heavily enrolled in workforce education and basic skills programs (as opposed to transfer), and a smaller student population of about 450 students.

Research on cultural competency of developmental education delivery, pedagogy, advising, etc. is extremely limited and very few interventions specifically address diverse student populations beyond responding to diversity of academic preparation. I am interested to know if colleges have developed or attempted to develop their own culturally competent methods for delivering developmental education program components (e.g. advising services in a student's native language).

A very similar technique was employed to choose the institution considered for a case study of an average performer. There were only three institutions that appeared on the average performance list for all three outcomes. Two of those institutions were in the same community college district as a previously chosen high performer. The third institution had a setting and students very similar to a previously chosen high performer. In order to maintain diversity of institutions the list was expanded somewhat to include some colleges that had one "below average" score (although close to the average cut-off) on one outcome variable. In this way a program in a suburban setting with a student population of about 1000 developmental math education students was chosen as the average performer (College T).

In the colleges, faculty and program administrators were interviewed using a protocol specific to their role. In addition, where permitted students were asked to participate in a focus group and/or interview and a protocol for students was developed (see interview protocols in the appendix).

For the administrator interviews, first, administrators familiar with developmental education because of their job roles or experience were approached (e.g. Vice Presidents of Instruction or Deans). Administrators were selected who have a central role in implementing,

designing, and/or evaluating policy or programs intended to strengthen students' success in developmental math (Patton, 2002). After the administrators agreed to participate, they approached faculty who had been teaching at each college since 2011 (the year data for the study begins), described the study, and asked for at least two full-time faculty volunteers and at least one part-time faculty volunteer. These same faculty volunteers were also asked to allow me to observe one of their classes. I was able to observe two developmental education courses in high performing College D and average performing College T. Administrators and/or faculty participants also announced the study in developmental math classrooms and/or the math tutoring lab and asked for student volunteers (except for College AA where student contact was not allowed as described earlier). Specifically targeted were students who had already passed at least one developmental math class in order to describe their experience transitioning from one class to the next level in terms of advising, curriculum alignment, classroom pedagogy, etc. Students were offered a \$10 Starbucks gift card for their participation. Student volunteers were therefore self-selected from a pool of courses where the announcements for participants were made.

Table 6. Case Study Participants

College	Faculty Participants	Staff Participants	Student Participants
College D (high)	5	2	6
College AA (high)	3	3	0
College T (average)	4	3	5

Data Collection

Data includes the transcripts of in-depth interviews of individual employees and students at the colleges, transcripts of focus groups held with developmental education students, and class observation and professional development observation field notes. Semi-structured interviews were conducted with six to seven college employees heavily involved in the developmental education program of the college. Interviewees included administrators, advisors, and faculty members, including part-time faculty, at each site in order to ensure a diversity of opinions about program features. In addition a focus group of six participants was held at College D among students who had completed at least one quarter of developmental education. One developmental education math class was observed at both College D and College T.

Interviews

The majority of the qualitative data for this study comes in the form of interviews. Interviews are defined as “A process in which a researcher and participant engage in a conversation focused on questions related to a research study” (DeMarrais, 2004, p. 55). In this case, semi-structured interview protocols were developed with the purpose to get as much information related to the research questions as possible. While protocols are in place for each participant group the semi-structured nature of the interview allows for some flexibility (Merriam, 2009).

Case study interviews for faculty and administrators focus upon several important developmental education topics, such as: 1) To what extent are identified best practices in play at the case study institutions; 2) The organization (i.e. separate unit for developmental education, separate faculty, etc.), definition, delivery, interventions, curriculum, pedagogy and support services most commonly found at the case study institutions; 3) The extent that traditional

models vs. new intervention approaches are being experimented at the colleges under study and what interventions are in place or have been tried; 4) The policies and practices that administrators and faculty believe to be salient to student success. (See faculty and administrator interview protocols in appendix).

Student Focus Groups and/or Individual Interviews

As a method of qualitative data collection, a focus group is an interview on a topic with a group of people who have knowledge of the topic (Krueger, 2008). Student focus groups are used here primarily as a triangulation device (Merriam, 2009). Participants included six students, five of whom had completed at least one level of developmental education and enrolled in a second level or beyond and one student who was in their first quarter of developmental math. Students addressed the presence of some of the best practices recommended by previous authors. For example, did the students feel that curriculum was aligned between their first and second level of developmental math? To what extent did they know about or use tutoring or other support services? Particularly interesting are students' views of what helped or hindered their success in developmental math courses. Student views have unfortunately very rarely been included in research on developmental education (Mitchell, 2013). At one of the colleges scheduling concerns hampered the organization of focus groups and I conducted individual student interviews instead with a total of five students. Therefore, a total of eleven student voices from two colleges are included in this research.

Class Observations

In addition, two programs allowed observation of developmental math courses, also primarily for triangulation purposes. Recent research by Grubb and colleagues revealed what he called "remedial pedagogy" to be common in 13 community colleges in California in Adult

Basic Education (ABE) classrooms, which was characterized by extremely dull “skill and drill” instruction (Grubb, 2013). Other authors have described a much more student-centered approach based on individual student talent development as a best practice (Boylan 2002). While pedagogy no doubt varies widely according to instructor even within one program, since so little is known about what happens in developmental math programs the descriptive information itself may have value and sheds light on policy and practice (and its variability) within classrooms, which is likely an important driver of student persistence.

During class observations I sat in the back of the room and quietly took notes without speaking to students. These field notes are a firsthand encounter with the teaching of developmental math and provide insight into how a student might experience a developmental math classroom. Observations were careful to be systematic, address a specific research question and subject to checks and balances so as to produce trustworthy results (Merriam, 2009). Referring back to the research questions, observations focused on evidence of best practices in the classroom, especially in terms of curriculum and pedagogy, evidence of the use of technology (or lack of it) in delivery, use of interventions (or lack of them) in the classroom. In both cases I made note of the physical setting, the participants, the activities and interactions present, the ongoing conversation, and other subtle factors such as nonverbal communication and what does not happen as well as how my presence in the room might have affected the scene observed (Patton, 2002; Merriam, 2009).

Coding & Analysis

Adhering to the suggestions of Bogdan and Biklen (2007), data analysis began simultaneous with data collection with both observations and memos generated relating to what may become important “issues raised in the setting and how they related to larger theoretical, methodological, and substantive issues” (p. 165). To guide the process of making meaning by

consolidating, reducing, and interpreting what people have said and done and what the researcher has seen and read, a constant referral back to the purpose and research questions of the qualitative case study is placed at the forefront. The purpose of this study is to describe how developmental math education is carried out on the ground in the three programs under study *and* gain a better understanding of the policies and practices that may promote student success in developmental math programs in community colleges from the perspective of administrators, faculty members and students.

A constant comparative method of data analysis was employed (Glaser and Strauss, 1967). In this tradition data analysis begins by identifying segments in the data that are responsive to the research questions (Merriam, 2009). These segments are units of data that are a potential answer or part of an answer to the research questions. I compared one unit of information with the next and looked at recurring regularities in the data that fell into some category, which together seemed to answer a research question. To begin this process I open coded my data. Through coding I built categories. While this technique is used by many traditions of qualitative research it is usually most associated with grounded theory where the categories are then sorted, named, possibly consolidated and then tied to some existing theory or hypothesis, if one exists, or described as a new theory or hypothesis if an existing theory is not available (Merriam, 2009).

Data collected was analyzed using NVivo research software, which allows custom coding according to specific themes or categories the researcher is interested in noting. Merriam (2009, p. 203) notes that case studies in particular have challenges that software can help address. “In addition to a tremendous amount of data, data sources may present disparate, incompatible, even apparently contradictory information. The case study researcher can be seriously challenged in

trying to make sense out of the data. Attention to data management is particularly important under these circumstances.” I follow the example of Lightfoot (1983) who studied six individual high schools and presented each setting as a “portrait” before offering a cross-case analysis. Yin (2008) recommends beginning “with a simple and straightforward case study” (p. 162) before moving on to a cross-case analysis (Yin, 2008; Merriam, 2009). I followed this suggestion and present cases individually followed by a cross-case analysis.

Maintaining reliability and validity

Several mechanisms were used to achieve high standards of credibility, dependability, and transferability. First, multiple sources of data (interviews among multiple stakeholders, inspection of documents and websites, class observations) were analyzed to triangulate data relative to participants’ claims, and increase the degree of trustworthiness that the data reflects reality as perceived within the community colleges and state context under study (Merriam, 2009).

Second, I conducted “member checks” to increase internal validity of data analysis through a process established for respondents to validate the data collected (Merriam, 2009). For example, in follow-up interviews and email correspondence, I debriefed findings to verify anything that remained unclear, relative to the study’s goals. During each interview, I provided periodic summaries of main points and understandings so as to have a verbal confirmation from the respondent of what was meant or stated where there were questions or doubts regarding meaning-making.

Thirdly, I maintained a record or “audit trail” of decisions I made regarding methods, procedures, and course corrections to ensure accurate reporting of study methodology, support

purposeful decision-making relative to the scope and questions of the research study, and strengthen reliability, dependability, and consistency of study processes and findings (Merriam, 2009). In a “grounded theory” approach, new decisions occurred constantly in data gathering, data analysis, and reporting of findings. Transferability of research findings was supported by “detailed description of the findings with adequate evidence presented in the form of quotes from participant interviews, field notes, and documents,” (Merriam, 2009, p. 227).

3.6 Validity, Generalizability, and Transferability of the Research

The validity, reliability and generalizability of mixed methods research is a topic of some debate (see, for example, Onwuegbuzie & Johnson, 2006; and Dellinger & Leech, 2007). However, the utility of a mixed methods study, from a pragmatic approach, is tied to whether it is a valuable approach that minimizes the weaknesses of either or both qualitative and quantitative approaches on their own. In this case mixed methods research not only minimizes the weaknesses in either strand but also adheres to the suggestions of Onwuegbuzie & Johnson (2011) by employing a sequential technique where the quantitative data inform selection of case study sites but also point to certain policies and practices that can be probed in qualitative research. In addition, I seek to add commensurability to the mostly quantitative analysis of developmental education outcomes that exists in the literature by including and processing different perspectives on what makes a program “successful.” I also seek to include the political considerations often missing from the largely quantitative body of research by addressing the interests, values, and standpoints of multiple stakeholders (i.e. students, administrators, and faculty) in the research process (see discussion of mixed methods “Legitimation” in Onwuegbuzie, Johnson & Collins, 2011).

The value of mixed methods lies in addressing limitations in what can be learned from one method (Creswell & Plano Clark, 2011). The same authors define validity in mixed methods research as employing strategies that address potential issues in data collection, data analysis, and interpretation that might compromise the merging or connecting of the quantitative and qualitative strands of the study and the conclusions drawn from the combination. They suggest several ways in which external validity (i.e. generalizability) may be strengthened including drawing quantitative and qualitative samples from the same population to make data comparable, finding quotes that match statistical results, and developing a joint display with quantitative categorical data and qualitative themes or using other display configurations (Creswell & Plano Clark, 2011). Other researchers have suggested that external validity or transferability (to the extent possible) of each of the individual strands of research (i.e. qualitative and quantitative) are the components that determine the validity of the mixed methods work (Teddlie and Tashakkori, 2009). The research here endeavors to satisfy both of these perspectives by adhering to as many of the suggestions for data integration between the two strands as possible as suggested by Creswell & Plano Clark (2011), but also by paying close attention to validity, transferability, and generalizability issues in each strand of the research as suggested by Teddlie and Tashakkori (2009).

One of the intended outcomes of this mixed-methods research effort is to offer findings to inform the state's community college completion agenda, and the specific role of improving developmental education completion and upward mobility rates. Multi-level modeling offers insight into how state and community college policies and practices matter (or do not) when working to increase student success, relative to specific student characteristics. While this research is drawn from a single state it does have the advantage of incorporating nearly the entire

population of students in low levels of developmental math in that state's community colleges and there is a large sample size. This quantitative research methodology will not, however, be effective in making true causal claims regarding the advantage from enrolling in community college programs with certain characteristics (Shadish, Cook, and Campbell, 2002). Rather, the analyses proposed here are designed to report factors statistically and/or qualitatively appearing to contribute to community college students' developmental education outcomes among one state's population of math developmental education students, and therefore to better inform policy related to these students.

Indeed, qualitative researchers have long suggested that the value of qualitative research lies in its transferability. They suggest that, "The burden of proof lies less with the original investigator than with the person seeking to make an application elsewhere. The original inquirer cannot know the sites to which transferability might be sought, but the appliers can and do." The investigator needs to provide "sufficient descriptive data" to make transferability possible (Merriam, 2009 p. 298). Other researchers suggest not generalizability of qualitative research but instead the idea of "working hypothesis" or "extrapolations" defined as not research conclusions but rather as tools for making better decisions or modest speculations about the likely applicability of findings to other situations under similar conditions (Cronbach, 1975; Patton, 2002).

While this research is only examining one state's community college system, I develop a "working hypothesis" (Cronbach, 1975) from this research that programmatic and institutional variation in the design and delivery of developmental education programs exists and that this variation can be described both qualitatively and quantitatively and connected to student outcomes. Finally, as in previous research looking at all community college students, I find that

there are institutional and programmatic features that are associated with success. These findings are described in detail below in chapters four and five.

Chapter 4

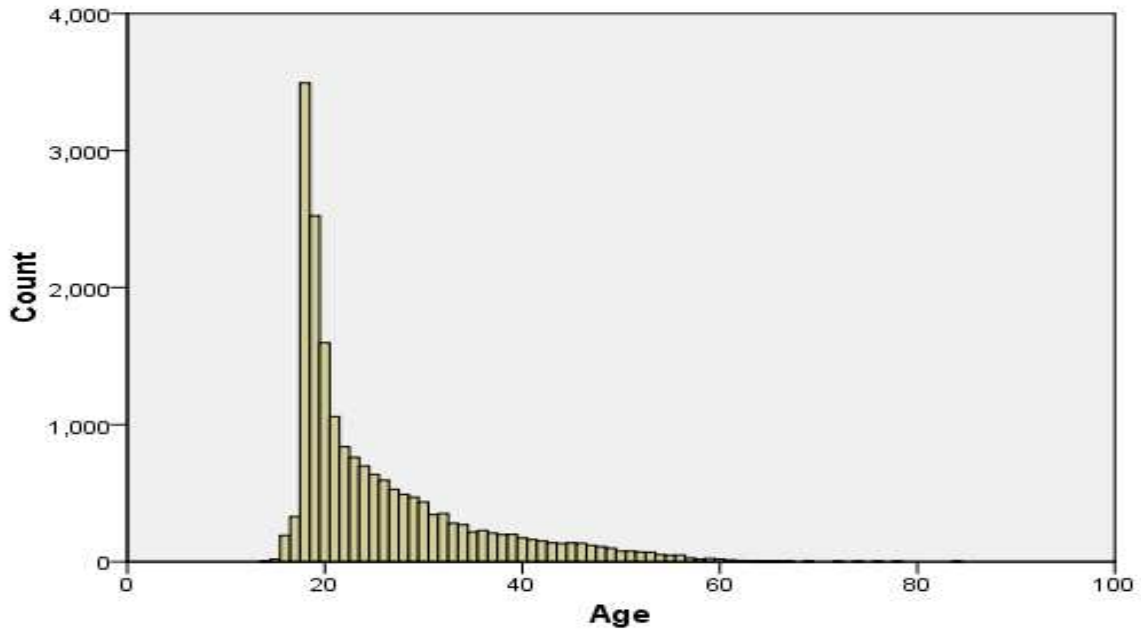
Math Developmental Education Policies and Practices Associated with Student Success: A Multilevel Models and Principal Components Analysis

4.1 Descriptive Statistics of Predictor Variables

The sample data analyzed consists of 16,877 students in all 28 community colleges in Washington who needed to pass as many as four, and a minimum of two, courses to reach a college level math class, and who [initially?] enrolled in fall 2011. Students who only needed one course were excluded to ensure the sample had adequate experience with the “treatment” of developmental math to answer the research questions. The smallest math developmental education program in the sample is Grays Harbor College with 240 students in fall 2011, while the largest is Clark College with 2,020 students enrolled.

Descriptive analysis of the data revealed some interesting information about the overall sample. The average age of students in the data is 25.5 years, very close to the average age of all community college students statewide, which is 26 years. However, a closer look at age data reveals that 7,273 students, 43.1% of the sample, are ages 18, 19, 20 or 21, meaning they likely have had fairly recent experience with high school math classes. An additional 439 students are age 17 or younger, likely participating in the Running Start (concurrent high school-college enrollment) program. However, this means that the majority of the sample, 9,660 students, 54.4%, are age 22 or over, so not recently in school.

Figure 2. Age of Students in Developmental Math Analytical Sample



The data also reveals that 50% of the students in the sample are receiving a Pell Grant. Statewide, one third of students receive a Pell Grant (David Prince, personal communication, Feb. 17, 2015). While there is no income cut-off for Pell Grants, they are based on financial need and the household income of students receiving a Pell Grant is very unlikely to be over \$60,000 annually (NCES, 2013).

Students were asked to self-report their race/ethnicity as well as SES and prior education on enrollment forms. Descriptive statistics for the analytical sample can be viewed in the tables below.

Table 7. Race/Ethnicity of Students in Developmental Math Analytical Sample

Race/Ethnicity	White	Hispanic	Multiracial	African American	Asian/Pacific Islander	Native American
% of Total	63%	12.7%	6.8%	6.4%	5.8%	1.8%

System-wide in Fall 2013, 7.8% of students were Black/African American, 2.9% were American Indian/Alaskan Native, 12.6% were Asian/Native Hawaiian/Pacific Islander, 15.9% were Hispanic, 2.1% were other, and 58.7% were white (WASBCTC, 2014).

Table 8. SES of Students in Developmental Math Analytical Sample

Annual Household Income Quintile	\$<27k	\$27k-50k	\$50k-76k	\$76K k-119k	>\$119k
% of Total	19.6%	20.1%	32.9%	20.1%	7.3%

Students were also asked on enrollment forms about their prior education. This field had 7.3% missing data. Just seven students of the total of 18,879 reported having less than a 9th grade education.

Table 9. Prior Education of Students in Developmental Math Analytical Sample

Highest Prior Education	<High School	High School or GED	Some College	AA	BA
% of total	15.0%	63.7%	18.4%	1.4%	.9%

The table below reports descriptive statistics for each variable in the dataset

Table 10. Descriptive statistics of sample (n=16,877 at Level-1; n=28 at level-2)

Variable	Mean	SD	Min	Max
<i>Dependent variables</i>				
Passed precollege math sequence	.42	.49	0	1
Passed college level math course	.32	.47	0	1
Highest momentum point reached	4.81	2.78	0	8
<i>Level-1 independent variables²²</i>				
Age	25.42	9.11	14	78
Pell	.5	.5	0	1
SES	2.74	1.19	1	5
Prior Education	3.14	.64	1	6
Starting level of precollege math	2.2	.77	1	4
Still enrolled	.29	.45	0	1
Underrepresented minority	.22	.41	0	1
<i>Level-2 independent variables²³</i>				
Student: faculty ratio in precollege math courses	24.96	4.35	18.39	40.62
# of levels of developmental math at the college	3.68	1.02	2	6
Use of Modules	.29	.46	0	1
Differentiated tracks	.39	.5	0	1
Assessment preparation course	.21	.42	0	1
Statway curriculum	.11	.31	0	1
Contextualized Instruction	.25	.44	0	1
Mandatory college orientation	.57	.5	0	1
College level math faculty also teach dev ed	.79	.42	0	1
Achieving the Dream participation	.54	.51	0	1
Alternative Placement	.21	.42	0	1
College mission statement reflects developmental education	.68	.98	0	3

Students in the sample have between two and four courses of developmental math ahead of them before reaching the college level. Where a student begins in the developmental math sequence depends on the structure of courses at the college, the college's assessment cut-off scores, and where the student scores on the assessment test. In this sample, 21.6% of students

²² Refer to variable definitions in Table 1, page 49.

²³ Refer to variable definitions in Table 3, beginning on page 51.

need to pass the course they were enrolled in during fall 2011 plus three additional courses to reach the college level. About 36.5% of the students will need to pass the course they were enrolled in plus two additional courses, and 41.9% of the sample have a total of two courses to pass before reaching the college level.

4.2 Descriptive Statistics on Outcomes

Analysis of the total sample with no controls reveals that 41.6% of the students passed and 58.4% did not pass the pre-college math sequence that they were enrolled in within the three-year time frame of the data. In addition, 32.3% of the total went on to pass at least one college level math course within the time span covered while 67.7% did not.

The final outcome variable examined was “momentum points.” Many community college students do not reach “terminal” outcomes, such as degrees. However research has shown that, during a student’s enrollment, particular course completions or other educational accomplishments can provide “momentum” that propels students toward the achievement of milestone events, such as the completion of a degree. These momentum points are measurable educational attainments that are empirically correlated with the completion of a recognized milestone (Leinbach & Jenkins, 2008). In this case the milestone in question is earning the “Completion Point,” a degree or certificate of at least 45 (quarter) credits, equivalent to one year of full-time study. As described earlier, this milestone has been proven to have positive labor market outcomes for students as a group (Prince & Jenkins, 2005). Thus, the third outcome variable examined was the highest “momentum point” achieved by the student on the pathway to earning a 45 credit certificate or degree.

The data show that 18.4% of students earned no momentum gains, meaning they never passed out of the developmental sequence in either math or English and never earned more than

15 college-level credits. A larger percentage of students who were in developmental math at the outset, 19.7%, did earn at least a 45 credit certificate or degree in the three years covered by this study. Many more students seem poised to reach this milestone: 19.1% of students passed a college level math course, and an additional 24.2% of students have earned at least 30 college level credits but have not passed college-level math in the three years covered by the data.

Table 11. Momentum Point Achievement of Students

<i>Momentum Point</i>	<i>Definition</i>	<i>Percentage of students achieving the point</i>
8	Student earned the Completion Point (at least a 45 credit certificate or degree)	19.7
7	Student passed a college level math course but earned no certificate ²⁴ or degree	19.1
6	Student earned 45 college level credits but did not pass a college level math course and earned no certificate or degree	4.2
5	Student earned between 30 and 45 college level credits	20.0
4	Student earned between 15 and 29 college level credits	12.5
3	Student passed developmental math but earned < 15 college-level credits	2.0
2	Student passed developmental English but earned < 15 college level credits	3.5
1	Student earned Basic Skills gains ²⁵ , but no other momentum gains	.6
0	Student made no momentum gains	18.4

These descriptive statistics regarding the outcome variables are on par with what previous studies have found. Bailey, Jeong, and Cho found that approximately 45% students nationally who had enrolled in developmental math completed their sequence within three years, and 33%

²⁴ Certificate must be at least 45 credits.

²⁵ Earned when a student moves from Basic Skills level courses to the developmental level.

of students who had initially enrolled in developmental math eventually passed college-level math (2010). Rates of remedial student success partly depend on the depth and breadth of one's skill deficits across the mathematics domain (Adelman, 2004; Bahr, 2010; Bahr, 2012). For example, Bahr (2008) analyzed data on 55,000 students who had enrolled in 107 California community colleges and found that only 8% of the students who had been placed into Basic Arithmetic (four levels below college math) successfully completed math remediation over three years, compared to 54% of the students who had been placed into Intermediate Algebra and Geometry (one level below college math). Momentum points are a somewhat unique indicator used in Washington and research has not examined the impact of developmental math on momentum point attainment but, since the momentum points are predictive of credential completion, they are worth studying.

Crosstabulations for passing precollege math by developmental education start level reveal that students who start four levels below the college level have a 24.5% probability of passing the precollege math sequence within three years, while the probability for students three levels below college level is 37.5% and for two levels below is 54.1%. Thus, starting level is an important predictor of whether the student will finish the pre-college sequence.

4.3 Multilevel Models: Does College Attended Have an Association with Passing the Developmental Math Sequence? What Program and Policy Variables Matter?

Hierarchical Generalized Logistic Models (HGLM) were employed for the two dichotomous outcome variables of whether the student passed out of the pre-college math sequence and whether the student passed any college level math course. To examine whether sufficient variation in precollege math completion rates and completion of a college level math course existed between programs (i.e. colleges), I estimated a fully unconditional model that had

no predictors at either Level-1 or Level-2. If the completion rates significantly vary among institutions, the use of HGLM is warranted.

In the null model the predicted logit for a typical college program in this sample is $\gamma_{00} = -.39$ (s.e. = .07), which is statistically different from zero, $t(27) = -5.37, p < .001$, and there was found to be considerable variability around the intercepts for this collection of schools $\tau_{00} = .14$, $\chi^2(27) = 544.95, p < .001$ for passing the pre-college math sequence. Estimated odds of attaining proficiency by completing the precollege math course sequence for students within a typical college is $\exp(-.39) = .68$ and thus the estimated probability of attaining such proficiency for these students is 40.48%. This estimate is close to the overall proportion of students (ignoring program variability) who passed pre-college math, as would be expected.

The intraclass correlation coefficient (ICC) was calculated using a method that assumes the outcome, Y , is a dichotomization of an unknown latent continuous variable, Y , with a level-one residual that follows the logistic distribution (Snijders & Bosker, 2012). The mean and variance of the logistic distribution are 0 and $\pi^2/3$, respectively (Evans, Hastings, and Peacock, 2000). Accordingly, the ICC based on this approach is .04, indicating about four percent of the variance in completion rates is attributable to programs, rather than individual variation on level 1 variables or other factors unexplained by the variables in the model.

Next, I proceeded by adding student level variables to the model. Table 12 contains the estimated coefficients and corresponding odds ratios for the fixed intercepts model based on results from a fixed coefficient model fit to these data. For this model, I first included all of the available predictor variables with respect to passing the precollege math sequence. Age was not found to be a statistically significant predictor and thus is not included in the results. The negative effect for underrepresented minority indicates that, if a student is a member of an

underrepresented minority, the estimated logit coefficient decreases by .17 units, yielding an odds ratio of .84. Not surprisingly, all other remaining variables, higher SES, higher prior education, and higher start level, yielded positive and significant results, indicating that all of these variables positively affect the odds of a student’s passing precollege math, holding all other variables constant. Start level is particularly influential.

Table 12. Multi-level Model of the Outcome Passed Precollege Math with Student Level Predictors

Variable	Coefficient	SE	Odds ratio	t-ratio	P
Intercept (pass precollege math)	-.41	.07	.66	-5.59	< .001
SES	.06	.02	1.06	4.23	< .01
Prior Education	.14	.03	1.15	5.04	< .01
Underrepresented Minority	-.17	.04	.84	-4.07	< .01
Start Level	.73	.02	2.07	30.29	<.001
Random Effects					
	Variance	DF	Chi-Square		P
Intercept	.14	27	493.23		< .001

Next, to address the research questions, I specified the within-college (Level-1) and between-college (Level-2) models to be estimated as follows.

Level 1:

$$\log [P_{ij}/1 - P_{ij}] = \beta_{0j} + \beta_{1j} * (SES)_{ij} + \beta_{2j} * (PriorEducation)_{ij} + \beta_{3j} * (Underrepresented Minority)_{ij} + \beta_{4j} * (Start Level)_{ij}$$

where P_{ij} is the probability of completing the precollege math sequence within three years.

Level 2 variables were entered into the model as individual steps and the order of the variables was based on theoretical considerations and also an analysis of significant zero-order correlations of predictor variables with the outcome variable of passing the pre-college math sequence:

$$\beta_{0j} = \gamma_{00} + \gamma_{01} * (\text{Alternative Placement})_{ij} + \gamma_{02} * (\text{College Faculty also teach Dev Ed})_{ij} + \gamma_{03} * (\text{Assessment Prep Course})_{ij} + \gamma_{04} * (\text{Differentiated Tracks})_{ij} + \gamma_{05} * (\text{Modules})_{ij} + \gamma_{06} * (\text{Number of Courses})_{ij} + \gamma_{07} * (\text{Orientation})_{ij} + \gamma_{08} * (\text{ATD})_{ij} + \gamma_{09} * (\text{Contextualized Instruction})_{ij} + \gamma_{010} * (\text{Mission})_{ij} + \gamma_{011} * (\text{SF Ratio})_{ij} + \gamma_{012} * (\text{Statway})_{ij} + \mu_{0j}$$

$$\mu_{0j} \sim N(0, \tau_{00})$$

$$\beta_{kj} = \gamma_{k0} \quad k=1, 2, \dots, 13$$

where β_{0j} indicates the average rate at which students pass the precollege math sequence for program j .

Because the focus of this study is to examine the effect of the program on passing precollege math, all Level-1 variables were group-mean centered. Group mean centering allows interpretation of the Level-1 intercept term, β_{0j} , as the unadjusted mean rate of passing the precollege math sequence for students with average values for personal background and academic achievement within a program. Group-mean centering is useful to disentangle individual from contextual effects (Raudenbush and Bryk, 2002). I allowed only the intercept to vary and fixed all student-level coefficients in the Level-2 model because the focus of the study is on the mean chance at the program level of a student's passing the precollege level math sequence rather than on the varying relationships between the student-level variables and the outcome variable.

Demographic variables (i.e., start level, prior education, underrepresented minority, and SES) were treated as control variables and entered in Step 1. Each program level variable was entered to examine whether there was any evidence of the policy variable's effect on passing pre-college math, and if so, whether the effects remained once other variables were considered. Table 5 presents the results of this analysis.

The upper part of the table presents the chi-square tests of the fit of the model. The chi-square statistic evaluates the goodness of fit of the model and a small chi-square indicates a better model fit. The “improvement chi-square” indicates whether the variables added in each step improved the fit of the model. This statistic is analogous to the F-Change test in multiple regression analysis (Peterson, Hawkins, Abbott, & Catalano; 1995). The parameter estimates for the demographic variables are not shown in this table but are controlled throughout the analysis.

As was seen in Table 13, alternative placement was significant in Steps 2, 3, 4, and 5, but once modules were added to the model in Step 6 it no longer had a significant direct effect. Colleges that offered an assessment preparation course also showed significant results even in the presence of variables representing alternative placement and math instructors who taught at both the college and developmental education levels, but, again, once modules was added to the model the presence of an assessment preparation course no longer had a significant direct effect on the probability of passing the course sequence. In fact, after step 6 none of the variables have a significant direct effect on the outcome.

Table 13. Hierarchical Logistic Regression: Developmental Education Program and Policy Components Predicting Passing Precollege Math Sequence, with Student Demographic Variables Controlled²⁶

Step	Model df	Chi-Square	Improvement Chi-Square
1. Demographics	27	493.23	
2. Alt placement	26	396.64	96.59***
3. College level instructors also teach dev ed	25	370.94	25.7***
4. Assessment prep course	24	303.44	67.5***
5. Differentiated developmental math tracks	23	288.73	14.71***
6. Math curriculum modules	22	257.55	31.18***
7. # Levels of developmental math	21	246.58	10.97***
8. Mandatory orientation	20	246.44	0.14
9. ATD membership (or participation)	19	245.45	0.99
10. Contextualized Instruction	18	245.01	0.44
11. College mission reflects dev ed	17	244.32	0.69
12. Student Faculty Ratio	16	235.48	11.84***

	Results Step 2			Results Step 3			Results Step 4			Results Step 5			Results Step 6			Results Step 7		
Variable	B	SE	p	B	SE	p	B	SE	p	B	SE	p	B	SE	p	B	SE	p
Alt Placement	0.4	0.16	0.02*	0.4	0.16	0.02*	0.36	0.14	0.02*	0.37	0.14	0.02*	0.29	0.14	0.06	0.28	0.15	0.08
College & Dev Ed Teachers				0.26	0.15	0.1	0.17	0.15	0.25	0.19	0.15	0.21	0.24	0.15	0.11	0.25	0.15	0.11
Assessment Prep							0.31	0.15	0.04*	0.32	0.15	0.04*	0.29	0.14	0.06	0.29	0.15	0.06
Diff Tracks										-0.1	0.08	0.32	-0.09	0.08	0.26	-0.16	0.09	0.11
Modules													-0.23	0.14	0.11	-0.14	0.15	0.36
Num Courses																-0.11	0.08	0.18

Table 13 Continued.

²⁶ Demographic variables controlled and not shown in this table: Start Level, Underrepresented Minority status, SES, Prior Education
 *** Significant at the $p < .005$ level * Significant at the $p < .05$ level

	Results Step 8			Results Step 9			Results Step 10			Results Step 11			Results Step 12			Results Step 13		
Variable	<i>B</i>	<i>SE</i>	<i>p</i>	<i>B</i>	<i>SE</i>	<i>p</i>	<i>B</i>	<i>SE</i>	<i>p</i>	<i>B</i>	<i>SE</i>	<i>p</i>	<i>B</i>	<i>SE</i>	<i>p</i>	<i>B</i>	<i>SE</i>	<i>p</i>
Alt Placement	0.28	0.15	0.09	0.28	0.16	0.1	0.29	0.18	0.13	0.3	0.19	0.13	0.32	0.19	0.11	0.3	0.31	0.35
College & Dev Ed Teachers	0.26	0.17	0.15	0.26	0.18	0.16	0.27	0.19	0.17	0.27	0.19	0.18	0.35	0.21	0.12	0.35	0.22	0.13
Review Course	0.29	0.15	0.07	0.29	0.16	0.09	0.29	0.17	0.1	0.28	0.17	0.12	0.28	0.17	0.12	0.29	0.19	0.14
Diff Tracks	-0.16	0.09	0.12	-0.16	0.16	0.09	-0.16	0.12	0.2	-0.16	0.12	0.19	-0.15	0.12	0.24	-0.15	0.14	0.3
Modules	-0.15	0.16	0.38	-0.15	0.17	0.39	-0.14	0.17	0.42	-0.13	0.18	0.47	-0.15	0.18	0.42	-0.15	0.19	0.46
Num Courses	-0.1	0.16	0.2	-0.1	0.08	0.23	-0.1	0.09	0.27	-0.11	0.09	0.25	-0.07	0.1	0.49	-0.08	0.12	0.53
Orientation	-0.01	0.15	0.94	-0.01	0.15	0.94	-0.01	0.15	0.93	-0.01	0.16	0.93	-0.01	0.19	0.62	-0.09	0.19	0.64
ATD				-0.01	0.17	0.93	-0.01	0.18	0.98	0	0.18	0.98	-0.05	0.19	0.8	-0.05	0.2	0.8
Contextualization							-0.03	0.18	0.87	-0.07	0.19	0.74	-0.06	0.2	0.77	-0.05	0.21	0.8
Mission										-0.06	0.09	0.52	-0.06	0.09	0.49	-0.06	0.09	0.51
SF Ratio													0.02	0.02	0.41	0.02	0.02	0.43
Statway																0.03	0.39	0.93

While none of the policy and practice variables have significant direct effects in the presence of all other variables, the two that show most promise, alternative placement policies and presence of an assessment prep course, are both variables related to avoidance of developmental math. Avoidance models seek to give students more opportunity to avoid developmental education altogether or to place them into higher levels than would be the case using a standardized placement test²⁷. The policies in the dataset reflecting such avoidance both seek to place students in the highest possible level in which they could succeed, often relying on multiple measures or utilizing the highest assessment between two measures. For example, at one of the case study colleges described in-depth later, students take both an assessment test and can submit their high school transcripts. Whichever assessment places them higher (if they vary) becomes the student's recommended course. Other types of policies or practices, for example, around acceleration (e.g. modules, differentiated tracks, Statway curriculum), teaching (e.g. reduction in student faculty ratio or faculty who teach at both college and developmental education levels), and cultural shifts (e.g. participation in Achieving the Dream or putting developmental education in mission or core themes) showed no significant effect or even a slightly negative effect, once other variables were included.

4.4 Multilevel Models: Does Program (College) Have an Association with Passing a College Level Math Course? What Program and Policy Variables Matter?

The same model construction was used for the second dichotomous outcome variable: whether the student passed a college-level math class within the three year time period of the study. First, a fully unconditional model with no predictors at either Level-1 or Level-2 was analyzed. In the null model the predicted logit for a typical college program in this sample is γ_{00}

²⁷ For a more full description of avoidance policies see Zachry-Rutschow and Schneider (2011).

= -.75 (s.e. = .05), which is statistically different from zero, $t(27) = -13.89, p < .001$. In addition, there was considerable variability around the intercepts for this group of colleges $\tau_{00} = .07, \chi^2(27) = 263.55, p < .001$. The estimated odds of completing a college-level course sequence for students within a typical college is $\exp(-.74) = .48$, and thus the estimated probability of this outcome for these students is 32.4%. This estimate is close to the overall proportion of students (ignoring program variability) who passed a college level math class within the three years under study.

Next, I again proceeded by adding student level variables to the model. Table 6 contains estimated coefficients and corresponding odds ratios for the fixed intercepts model based on results from a fixed coefficient model fit to these data. For this model, I first included all of the available demographic predictor variables with respect to completing a college level math class. Just as in the results for passing the precollege math sequence, age was not found to be a statistically significant predictor of whether the student passed a college level math class in the three years and thus is not included in further analyses or the results. Student SES was also not predictive of the outcome and thus is also excluded. If a student is an underrepresented minority, the estimated logit coefficient decreases by .09 units, yielding an odds ratio of .91, implying that URM students are 91% as likely to achieve this outcome. Not surprisingly, higher prior education, and higher start level within the developmental math sequence yielded positive results, indicating that all of these variables positively affect the odds of a student passing a college-level math course, holding all other variables constant. Again, start level is particularly influential.

Table 14. Multi-level Model of the Outcome Passed a College Level Math Course with Student Level Predictors

Variable	Coefficient	SE	Odds ratio	t-ratio	P
Intercept (pass college level math course)	-.77	.06	.47	-13.74	< .001
Prior education	.07	.00	1.07	2.47	< .01
Underrepresented Minority	-.09	.02	.91	-2.20	< .05
Start level	.62	.02	1.62	19.68	< .001
Random Effects					
	Variance	DF	Chi-Square		P
Intercept	.08	27	272.53		< .001

Next, to address the research questions, I specified the within-college (Level-1) and between-college (Level-2) models to be estimated as follows.

Level 1:

$$\log [P_{ij}/1 - P_{ij}] = \beta_{0j} + \beta_{1j} * (\text{PriorEducation})_{ij} + \beta_{2j} * (\text{Underrepresented Minority})_{ij} + \beta_{3j} * (\text{Start Level})_{ij}$$

where P_{ij} is the probability of completing a college level math course within three years.

Level 2 variables were again added individually to the model, with those variables with the highest association with the outcome of passed precollege math added first under the assumption they again would be important for the outcome variable of passing college level math:

$$\begin{aligned} \beta_{0j} = & \gamma_{00} + \gamma_{01} * (\text{Alternative Placement})_{ij} + \gamma_{02} * (\text{ReviewCourse})_{ij} + \gamma_{03} * \\ & (\text{CollegeFacultyTeachDevEd})_{ij} + \gamma_{04} * (\text{Differentiated Tracks})_{ij} + \gamma_{05} * (\text{Modules})_{ij} + \gamma_{06} * \\ & (\text{NumberofCourses})_{ij} + \gamma_{07} * (\text{SFRatio})_{ij} + \gamma_{08} * (\text{Mission})_{ij} + \gamma_{09} * (\text{Orientation})_{ij} + \gamma_{010} * \\ & (\text{Contextualization})_{ij} + \gamma_{011} * (\text{ATD})_{ij} + \gamma_{012} * (\text{Statway})_{ij} + \mu_{0j} \end{aligned}$$

$$\mu_{0j} \sim N(0, \tau_{00})$$

$$\beta_{kj} = \gamma_{k0} \quad k= 1, 2, \dots, 12$$

where β_{0j} indicates average rates of passing a college level math course for program j .

Again, all variables were group mean centered and, just as with the analysis of factors associated with passing the precollege math sequence, I allowed only the intercept to vary and fixed all student-level coefficients on the Level-2 model.

Table 15. Hierarchical Logistic Regression: Developmental Education Program and Policy Predicting Passing a College Level Math Course, with Student Demographic Variables Controlled²⁸

Step	Model df	Chi-Square	Improvement Chi-Square
1. Demographics	27	272.53	
2. Alt Placement	26	227.72	44.81***
3. Review Course	25	227.67	0.05
4. College Faculty also teach dev ed	24	220.63	7.04**
5. Diff Tracks	23	215.6	5.03*
6. Modules	22	187.2	28.4***
7. Num Courses	21	179.87	7.33**
8. SF Ratio	20	178.48	0.39
9. Mission	19	162.95	15.53***
10. Orientation	18	155.5	7.45**
11. Contextualization	17	130.75	24.75***
12. ATD	16	120.38	10.37***
13. Statway	15	118.59	1.79

Variable	Results Step 2			Results Step 3			Results Step 4			Results Step 5			Results Step 6			Results Step 7		
	B	SE	p	B	SE	p	B	SE	p	B	SE	p	B	SE	p	B	SE	p
Alt Placement	0.3	0.15	0.04*	0.29	0.16	0.1	0.31	0.16	0.06	0.31	0.16	0.07	0.25	0.16	0.13	0.22	0.16	0.2
Review Course				0.03	0.13	0.8	-0.01	0.14	0.95	0.01	0.14	0.94	0.04	0.14	0.79	-0.04	0.14	0.76
Faculty Overlap							0.13	0.14	0.37	0.13	0.14	0.38	0.16	0.14	0.24	0.17	0.14	0.22
Diff Tracks										0.01	0.08	0.94	0	0.07	0.99	-0.05	0.09	0.58
Modules													0.22	0.12	0.08	-0.16	0.13	0.25
Num Courses															-0.07	0.07	0.3	0.18

²⁸ Demographic variables controlled and not shown in this table: Start Level, Underrepresented Minority status, Prior Education

*** Significant at the p<.005 level

** Significant at the p<.01 level

*Significant a the p<.05 level

Variable	Results Step 8			Results Step 9			Results Step 10			Results Step 11			Results Step 12			Results Step 13		
	<i>B</i>	<i>SE</i>	<i>p</i>	<i>B</i>	<i>SE</i>	<i>p</i>	<i>B</i>	<i>SE</i>	<i>p</i>	<i>B</i>	<i>SE</i>	<i>p</i>	<i>B</i>	<i>SE</i>	<i>p</i>	<i>B</i>	<i>SE</i>	<i>p</i>
Alt Placement	0.22	0.16	0.19	0.18	0.16	0.27	0.16	0.16	0.32	0.08	0.17	0.66	0.11	0.17	0.52	-0.06	0.25	0.82
Review Course	-0.05	0.14	0.72	-0.06	0.13	0.65	-0.09	0.14	0.54	-0.08	0.13	0.55	-0.12	0.14	0.39	-0.05	0.16	0.74
College Faculty also teach dev ed	0.15	0.14	0.28	0.14	0.14	0.32	0.04	0.17	0.83	-0.02	0.17	0.9	0.01	0.17	0.94	0.01	0.17	0.94
Diff Tracks	-0.08	0.09	0.4	-0.09	0.09	0.34	-0.1	0.09	0.28	-0.1	0.08	0.25	-0.14	0.09	0.17	-0.19	0.11	0.11
Modules	-0.18	0.14	0.2	-0.15	0.13	0.26	-0.1	0.14	0.47	-0.13	0.14	0.37	-0.16	0.14	0.28	-0.11	0.15	0.5
Num Courses	-0.1	0.07	0.06	-0.12	0.07	0.10	-0.14	0.08	0.07	-0.17	0.08	0.04*	-0.15	0.08	0.07	-0.19	0.15	0.05*
SF Ratio	-0.02	0.01	0.27	-0.01	0.01	0.3	-0.02	0.02	0.16	-0.02	0.02	0.15	-0.02	0.07	0.24	-0.02	0.02	0.26
Mission				-0.09	0.07	0.18	-0.09	0.08	0.19	-0.06	0.07	0.36	-0.06	0.07	0.38	-0.08	0.07	0.28
Orientation							0.16	0.15	0.29	0.16	0.14	0.28	0.15	0.14	0.3	0.15	0.14	0.32
Contextualization										0.21	0.14	0.16	0.25	0.15	0.11	0.26	0.15	0.1
ATD													-0.14	0.15	0.39	-0.13	0.16	0.41
Statway																0.25	0.27	0.37

The only policy variable that was significant and remained significant even in the presence of all other variables was the variable that measures the minimum number of developmental education courses a student must test out of or pass (“Num Courses”) before entering a college level math course. Specifically, the odds ratio of .83 indicates that for every additional developmental education math course a program has prior to the college level, the odds of a student’s passing a college level math course decrease by 17%, holding all other variables constant.

4.5 Multilevel Models: Does College Attended Have an Association with Highest Education Attained? What Program and Policy Variables Matter?

To assess the association between program policy and practice variables and highest momentum point achieved, hierarchical linear modeling (as opposed to hierarchical generalized linear modeling) was employed because of the continuous nature of the outcome variable. Model testing proceeded in three phases using HLM version 7.01: first the unconstrained (null) model, then the fixed effects student level model, and finally a model with program level variables. The first HLM analysis partitioned the variance in the students’ highest momentum point achieved at the individual level and the program level. In the analysis of the unconditional HLM model (i.e. a model with no explanatory variables included) for the outcome variable of maximum momentum points, the statistically significant between-program variance indicates that average point accumulation varied across Washington community colleges ($\text{var}(u_{0j}) = .07, \chi^2(164.81, p < .001)$). A very small (but significant $p < .001$) Intra Class Correlation of highest momentum point reached by a student can be explained by variation in college attended: .01. Thus, only 1% of the variation in maximum momentum point reached by students can be explained by developmental math program variation between colleges. However, because significant variance

existed at both levels of the data structure, HLM as opposed to linear regression is the appropriate statistical technique and predictor variables were added.

Adding in student level controls, three statistically significant student-level variables were found, with variables centered around their grand mean: Age, precollege math start level, and whether the student was an underrepresented minority. Higher age and higher start level were both uniquely positively associated with momentum points while, again, underrepresented minority status was negatively associated with momentum points attained. Neither SES nor prior education were found to be significant for this outcome and thus are not included in the results table.

Table 16. Multi-level Model of the Outcome Highest Momentum Point Achieved, with Student Level Predictors

Variable	Coefficient	SE	t-ratio	P
Fixed Effects				
Intercept (maximum momentum point)	4.80	.05	89.38	< .001
Age	.02	.00	9.40	< .001
Start Level	.65	.03	21.72	< .001
Underrepresented minority	-.25	.05	21.72	< .001
Random Effects				
	Variance	Df	Chi-Square	P
Intercept	.07	27	164.81	<.001
	7.42			
Proportion of Variance Explained				
	Within Programs	.03	Between Programs	0

For this outcome, in comparison to the null model, the student characteristics model explained 3% of the variance at the student level and none of the variance at the program level.

The intercepts for the student model, β_{0j} , represent adjusted means for each program or college. College average momentum point achievement becomes more homogenous after it is adjusted within each school for the three significant predictor variables. This explains the reduction in the variance at the college level even though no college level variables are present.

Because of the reduction in the variation at the college level, I proceeded with a means as outcomes model without student level predictors to determine whether any level 2 variables were significant without any controls at level 1. Predictors were based on theoretical considerations. None of the level 2 variables tested yielded significant results without the level 1 controls. Thus, there is a very small amount of variance in momentum point outcomes for students between community colleges in Washington, at least among this population of math developmental education students, and once student background characteristics are controlled, no college variance can be detected.

4.6 Principal Components Analysis: Can Developmental Education Programs be Categorized in a Meaningful Way?

Principal Components Analysis maximizes the percentage of variance in a data distribution explained by extracted linear combinations of variables and values used to create components (Sanders, 2012). The number of principal components is less than or equal to the number of original variables. This transformation is defined in such a way that the first principal component has the largest possible variance (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it is orthogonal to (i.e., uncorrelated with) the preceding components. Often, its operation can be thought of as revealing the internal structure of the data in a way that best explains the variance in it (Sanders, 2012).

Because the dataset has only 28 colleges it was necessary to combine the predictor variables into theoretically related groups to reduce the policy predictor variables from the original 12 in order to maintain statistical validity and reduce the N-to-predictor variable ratio (Abbott, personal communication, January 2015). I thus took the four program variables related to accelerating a student through the developmental sequence (i.e. Modules, Contextualization, Statway, and Differentiated Tracks) and transformed them into one “Acceleration” variable. Similarly, two policies related to helping students avoid the developmental math sequence if possible were combined into an “Avoidance Strategies” variable. Another small group of variables were arguably related to institutional commitment to developmental education. Two linear variables, student-faculty ratio and the minimum number of developmental education courses a student must pass in order to achieve the college level, were also included. Table 9 describes the variables used in the PCA analysis.

Table 17. Descriptive Statistics of Variables used for PCA

Variable	Mean	SD	Min	Max
1. Acceleration Strategies (Modules + Contextualization + Statway + Differentiated Tracks ²⁹)	1.36	1.31	0	5
2. Avoidance Strategies (Alternative placement + Assessment Prep Course)	.36	.62	0	2
3. Institutional Commitment to Dev Ed (Mission statement + Core themes + Achieving the Dream participation)	1.04	.88	0	3
4. Number of courses before the college level	3.68	1.02	2	6
5. Student-faculty ratio	24.96	4.35	18.39	40.62

²⁹ Colleges could receive up to two points in in the variable of Differentiated Tracks. If they had only one developmental math track for all students they received 0 points, if they had more than one track they earned 1 point, while if they had more than one track and at least one track allowed some students to accelerate (i.e. pass fewer courses) to achieve college level, they earned 2 points. The Differentiated tracks score was added to modules (0,1); Contextualization (0,1) and Statway (0,1) to create a five point continuous composite variable. In the same way Avoidance Strategies is composed of Alternative placement (0,1) with Prep course (0,1).to create a continuous composite variable. As is Institutional Commitment to Dev Ed composed of (Mission statement 0,1) and Core themes (0,1) plus Achieving the Dream participation (0,1) to create a composite variable. The two remaining variables Number of courses before the college level and Student faculty ratio were already continuous and didn't undergo any transformation.

A principal components analysis of the variable correlations indicated that two components had eigenvalues >1 and could account for 60% of the variance in the original set of variables. There was no indication of problematic variables in the commonalities, since all were $>.40$ and averaged $.61$. Commonalities above $.4$ indicate that the variable is an acceptable fit in the correlation matrix (Sanders, 2012).

Table 18. Component Loading

Variable	Component 1	Component 2
Acceleration strategies	-.77	.14
Avoidance strategies	-.34	.60
Institutional commitment to dev ed	.72	.13
Number of courses before the college level	.38	-.72
Student to faculty ratio	.45	.70

An analysis indicates that programs more heavily loading on Component 1 seem to have relatively traditional developmental education programs. They exist in colleges with a comparatively high level of external commitment to the developmental education mission (as opposed to programs loading on Component 2), they have few, if any, avoidance strategies, a smaller student to faculty ratio, few, if any, acceleration strategies, and a higher number of courses a student must pass to reach the college level. In contrast, programs loading heavily on component two show a relatively innovative approach with some avoidance strategies, some acceleration strategies, and a relatively shorter course sequence to achieve the college level. These colleges also have slightly higher student to faculty ratios and show less (at least rhetorical) commitment to developmental education in their mission.

4.7 Logistic Regression of Program Components: Are the Program Types Associated with Either Positive or Negative Student Outcomes?

To determine whether programs loading heavily on either component were associated with the outcome of passing precollege math, factor loading scores for each component in each developmental education program under study were calculated. Scores ranged from -1.81 to 2.03 on Component 1 and -2.06 to 2.21 on Component 2. The calculated scores were transformed into standardized (Z) scores for ease of interpretation. Controlling for significant student background characteristics, the component scores were added as independent variables (i.e. predictor variables) in analyses on the two outcome variables of passing precollege math and passing a college level math course, respectively, in logistic regressions using SPSS version 21.

A test of the full model with the set of predictors against the null model with no predictors for the outcome of passing the developmental math sequence showed a significant difference, $\chi^2(1) = 185.72, p < .001$, which indicates that the set of predictors reliably distinguishes individuals who passed the precollege math sequence from those that did not, net of the individual level variables. Controlling for the significant student background characteristics of prior education, developmental education start level, SES, and underrepresented minority status, Component 2 was significantly uniquely predictive of rates of passing the developmental math sequence, $b = .19 (SE .02)$, $Wald(1) = 105.62, p < .001, OR = 1.21$. Holding Component 1 constant, students attending programs with relatively higher loadings on Component 2 (i.e. emphasizing avoidance techniques, shorter sequence, and some acceleration) had 21% higher odds of passing the precollege math sequence.

Finally, although it had a significant and negative zero-order correlation with college rates of passing the developmental math sequence, Component 1 did not *uniquely* predict passing

the developmental math sequence, $b = .00$ ($SE = .02$), $Wald(1) = .03$, $p = .87$, in the presence of the other predictors.

Table 19. Logistic Regression Model of the Outcome Passed Precollege Math with Program Typology Predictors³⁰

Variable	B	SE	p	OR
Intercept	-2.297	.10	<.001	.10
Component 1 (Traditional Model)	.00	.02	.87	1.00
Component 2 (Innovative Model)	.19	.02	<.001	1.21

Next, the same components were tested against the outcome of passing a college level math course, controlling for significant student background characteristics of underrepresented minority status, prior education, and developmental education start level. Again, component 2 showed a significant positive association $b = .06$ ($SE = .02$), $Wald(1) = 9.0$, $p < .01$ with this outcome. Students attending colleges with higher loadings on component 2 had a 6% greater chance of passing a college level math course. In this model, component 1 showed a negative association with the probability of passing a college-level math class, although shy of statistical significance at the conventional .05 level: $b = -.04$ ($SE = .02$), $Wald(1) = 3.03$, $p = .08$.

Table 20. Logistic Regression Model of the Outcome Passed a College Level Math Class with Program Typology Predictors³¹

Variable	B	SE	p	OR
Intercept	-1.88	.04	<.001	.15
Component 1 (Traditional Model)	-.03	.02	.08	.97
Component 2 (Innovative Model)	.06	.02	<.01	1.06

³⁰ Significant student background characteristics controlled for but not shown in the table include underrepresented minority status, developmental education start level, prior education, and SES.

³¹ Significant student background characteristics controlled for in the model but not shown in the table include underrepresented minority status, prior education, and developmental education start level.

These two analyses seem to indicate that programs with approaches emphasizing avoidance of developmental math such as alternative placement (e.g. transcript evaluation for placement, assessment tests developed by program faculty), fewer courses in the developmental math sequence, and some acceleration techniques (e.g. differentiated, shortened tracks) have moderately more positive student outcomes in terms of both passing the developmental math sequence and passing a college level math class than programs with a more traditional approach.

4.8 Limitations to the Quantitative Data and Analysis

Several key challenges arise in the investigation of impacts of developmental education programmatic policies and practices on the success rates of students in developmental math. The first has to do with limitations of available data. While the dataset is rich in that it contained the entire sample of students in the first levels of developmental math courses in fall 2011 in Washington community colleges, several problems are inherent. First, a small amount of missing data meant that not all students are represented in the data set analyzed; about 8% of the total sample was eliminated due to missing data. In addition, each variable included for analysis passed a Missing Completely at Random (MCAR) test in SPSS v. 21 (Little, 2002). Second, the dataset is missing several key variables that previous studies have found to be important in student success, for example, gender and full-time or part-time student status. Also not included is whether the student intended to transfer to a four-year institution or earn a terminal professional-technical degree. The student intent variable was included in the original dataset but did not pass Little's MCAR test (Little, 2002). These variables have been shown to be significant in previous research and would have been desirable to include. Their inclusion most likely would have increased the level of variance accounted for at the student level.

Another challenge of this research is that often policies and practices in community colleges are implemented over time, in a somewhat fluid and loosely documented manner, and sometimes with limited groups of students. I tried to measure only policies and practices that were in place for the majority of students in a college's developmental math program over the entire three year time period of the study by consulting college web sites, college personnel, and personnel from the State Board for Community and Technical Colleges who have on the ground knowledge of college policy in practice. But, inevitably some students were not aware of or eligible for certain interventions that I attributed to their program. These kinds of problems make it difficult to find statistically significant results and likely the results I report thus are conservative. In MDRC studies involving randomized controlled trials of various types of interventions (student performance incentives, mentoring, student success seminars, bridge programs from high school to college, etc.), scholars have noted challenges in capturing changes to program implementation and aligning data analytic methods and comparisons with those changes in practice and policies that may be influencing outcomes of a particular intervention. This is a common concern in evaluation studies throughout education and human services.

Scholars have also noted an important methodological concern in studies of community college students with respect to how measures of constructs in higher education research are operationalized relative to the particular concerns and characteristics of these students. Examples include academic and social integration constructs (Deil-Amen, 2011) and the role of social and cultural capital in explaining student outcomes (Wells, 2008). As this research was largely exploratory, I was unable to measure quantitatively what contributions variables such as level of student academic or social engagement at the college might add, but this would be desirable in subsequent studies.

This quantitative inquiry also does not include the influence of college-level characteristics (as distinct from developmental education program policies and practices) beyond the inclusion of the generic variable about mention of developmental education in the college's mission documents. I did run several models with program size as a predictor variable but none were significant. However, there may be some institutional characteristics that are significantly associated with student success (see, for example, Bailey et al. 2005).

Finally, this dissertation only examines one statewide system that, by virtue of a relatively strong state organization coordinating some policies across institutions (i.e. the Washington State Board for Community and Technical Colleges), might display more homogeneous policy across colleges than is found in other states.

4.9 Discussion of Findings

Overall, three points can be made about this analysis. First, there is very little—indeed in this analysis no—difference between institutions in SAI point accumulation once student background characteristics are taken into account, at least for this population of students. While multi-level modeling is appropriate, small ICC and r^2 values indicate that only small amounts of variance at each level are captured by the variables in the model. If colleges themselves do not seem to be contributing much, if anything, to the variance in point achievement between colleges, and even student characteristics are not very predictive of these outcomes, it calls into question the relationship between some common college policy levers, including the Student Achievement Initiative, and the ability to affect performance. Furthermore, if colleges have little control through policy or practice over student outcomes it seems that unexplained factors must be largely at work.

One possible explanation, which has yet to be proven, is that the point system may reward colleges with “better,” less disadvantaged students who can more easily achieve the milestones measured. A number of studies have called into question the efficacy of pay for performance schemes for community colleges (Hillman, Tandberg, and Hicklin-Fryar, 2014; Dougherty, Jones, Lahr, Natow, Pheatt & Reddy, 2014; Dougherty & Reddy, 2011) despite the fact that 33 states now have some form of performance funding in higher education (National Conference of State Legislatures, 2015). However, no study to date has employed an HLM technique to assess whether and how much variation in student outcomes exists between colleges. In Washington, and perhaps in many other states, it appears that the assumption that some colleges overall do a better job than others and should therefore be rewarded using the existing scheme may be unproven and in need of further research. [See previous comment.]

The two strongest predictors of student outcomes I found were the developmental course level at which a student started her or his developmental education math career and whether the student was a member of an underrepresented minority group. If these are indeed the biggest predictors of student success, they may point to other policy avenues (e.g. efforts at culturally relevant teaching in the latter case) unaddressed by current reform initiatives targeted at developmental math education.

Second, while there seems to be little if any overall variation in momentum point achievement in community colleges for this student population, this analysis does suggest that there are some things colleges can do to help students attain the more proximal outcomes of passing the developmental math sequence and passing a college level math course. In particular, it seems that helping students avoid the developmental math sequence, or at least some of it, via suitable alternatives, and accurately placing students in the highest developmental math course in

which they may be able to succeed are important to success. While limited research exists, Belfield and Crosta (2012) found that placement tests commonly used by community colleges do not yield strong predictions of how students will perform in college. In contrast, high school GPAs are useful for predicting many aspects of students' college performance, and have a strong association with college GPA. The authors found that using high school GPA instead of placement tests would reduce the severe error rates in the system by half across both English and math.

Washington is actively pursuing partnerships that more closely link high school curriculum to college standards and, for students like the 45% in this sample who are recent high school graduates, such efforts may be the most helpful in their pursuit of a college credential. This study, like others (Safran & Visher, 2010; Fay, Bickerstaff, & Hodara, 2013), finds that, for those students who may not benefit from alternative placement by GPA, placement by faculty-developed testing instruments or by taking a review course prior to an assessment test may help them place into a higher level of developmental math that will lead to better results in the end (Safran & Visher, 2010; Fay, Bickerstaff, & Hodara, 2013).

Third, limiting the number of courses in the developmental math sequence and not adding extra courses for some students while streamlining pathways for other students seems important. While researching student pathways, I was surprised to find that over half of the community colleges in the state had implemented some version of an accelerated pathway. In most cases, they had created a shortened sequence through developmental math for students not pursuing a STEM major or degree. Research recommends shortening developmental math sequences (see for example, Cho, Kopko, Jenkins, and Jaggars, 2012; Edgecombe, 2011; Bragg, Baker, Puryear,

2010) and differentiated tracks have emerged as a popular strategy for students who are not STEM majors. These students would experience developmental and college level math classes that are focused on statistics or applied math topics as opposed to the traditional algebra pathway that is arguably not relevant for them and a major hurdle.

I found only a slight association between differentiated tracks and student success in Washington, however. I noticed that many colleges that had implemented shortened pathways for some students may have also lengthened or made the content more difficult in courses and sequences in the traditional algebra-based sequence now intended primarily for STEM majors. It seems possible that shortening the pathway for some students while lengthening it or making it more difficult for others may be limiting the overall student success rate. This hypothesis is explored more in the case studies presented in chapter 5.

Despite finding little variation in highest level of education reached (i.e. momentum point gains), I did find significant college-level variation in the outcomes of probability of passing the developmental math sequence and of passing a college level math course. I also found that programs could be empirically typed as more traditional or more innovative, and that certain types of programs displaying the more innovative avoidance strategies and at least some acceleration strategies seemed to be associated with positive student outcomes, such as passing the pre-college math sequence and passing a first college level math course. Case studies in three community colleges sought to further explore this variation and student, administrator, and faculty member insights into successful policies and practices “on the ground.” These are presented in the ensuing chapters.

Chapter 5

Math Developmental Education on the Ground: Qualitative Case Studies in Three Colleges

5.1 Introduction & College Descriptions

These case studies highlight three developmental math programs in Washington, selected for their achievement on the three student outcome variables described above and then for their representation of setting and student population diversity within the system. The case studies explore the differences between programs, provide lessons in designing and operating developmental math programs, and provide an “on the ground” assessment of program features from program administrators, faculty members, and students. The purpose of this research is to complement the quantitative findings described by gaining a better understanding of the policies and practices that may promote student success in developmental math programs in community colleges from the perspectives of administrators, faculty members and students who have valuable experience in these programs. The research also describes the variation in math developmental education programming in these three colleges, and uncovers nuances and promising practices that may be important for student success and may not have been captured fully in the quantitative research alone.

These case studies offer insights and knowledge regarding: 1) community college students’, administrators, and faculty members perspectives about factors enhancing or deterring student progression in developmental math sequences; 2) the extent to which identified best practices are in play at the case study institutions; 3) how developmental math is defined, organized in terms of course structure, delivered in terms of technology, interventions in place,

curriculum and pedagogy, and supported in terms of resources at the community colleges under study; and 4) to what extent traditional models versus new intervention approaches are being experimented with at the colleges under study.

Two of the case study colleges (College D and College AA) were chosen because they were found to be “high achievers” in the quantitative results. After controlling for student background characteristics, their results for all three outcome variables described earlier were in the top third of performers. The third college (College T) was a more average performer, with results in the middle third of colleges on two outcome variables and the bottom third (although very close to the cut-off) on one outcome variable, after controlling for student background characteristics.

College descriptions

All three colleges were established between 1965 and 1970. College AA, a high achiever, is part of a large urban community college district. Some administrative functions are shared with other colleges in the district but the college has its own president and at the developmental math program level has relatively autonomous decision-making authority. The college is relatively small compared with others in the system and has a headcount enrollment of about 7,000 degree or certificate seeking students each academic year. It enrolls about 450 students in its developmental math program.

College D, also a high achiever, is not part of a community college district and is located in a mid-sized city in an otherwise rural area. The headcount enrollment is about 11,000 students per year. It has a large developmental math program that enrolls more than 1,000 students per year.

The largest of the three colleges, College T, is a more average achiever. It is a suburban college with an annual enrollment of about 33,000 students. It also has a student population of over 1,000 students annually in developmental math. As is typical of many community colleges, in all three of these colleges most students in the college are female, most attend part time, and most receive some form of financial aid.

Administrators and faculty I spoke with at the three colleges described three distinct groups of students attending developmental math courses. In all three colleges they categorized students by age or life stage. First, they described the recent high school graduate; these students are very young, probably in their first college experience and only recently out of the high school. They likely were average or poor math students in high school and several instructors I spoke with at all three colleges described them as “at-risk” because of their lack of study skills and said, “They often have a hard time asking for help, they are unsure sometimes whether they even need help or where to go or ask. I see a lot of them just kind of fade away.”

The second group that instructors describe are the slightly older (although still relatively young) group of students with jobs and families. These students have likely already been in college at least once and have re-enrolled. Instructors said they tend to be more motivated than the younger group. They see the value in an education but “they have a lot going on: kids, family, at least one job, they have to figure out how to pay the tuition.” This may also not be their first enrollment in developmental math and they often display confidence gaps in their math abilities.

The final population group that instructors describe are older students who are returning to college through a retraining program to pursue a career change. While this population has decreased somewhat since the end of the recession, instructors still saw these students as a

distinct population who were in the community college with an employment goal in mind. These students might decide to re-enter the workforce before completing their education if given the opportunity. All three groups might include students with cognitive or emotional difficulties or students who were not proficient in English, and instructors openly discussed the difficulty of how to meet the needs of these diverse types of individuals.

Like other community colleges around the country, these three colleges display high placement rates into developmental education and in particular, developmental math, and success rates are a concern. While two of these colleges have higher than average success rates according to my analysis, still about half of the students who enroll in developmental math sequences will not complete the sequence within three years.

5.2 Case Study: Components and Perceptions of the Developmental Math Program at College D

Description of the Student Population at College D

College D, a high performing institution, is located in a mid-sized city in an otherwise rural area of the state. The students at this community college are mostly younger (66% are under age 24) and 81% of degree-seeking students are pursuing an academic transfer degree as opposed to a professional-technical (workforce) degree. Because this community college is located in a city with a university and considered a “college-town” most of the students have the goal of transfer to the nearby university.

Developmental Math Program Organization

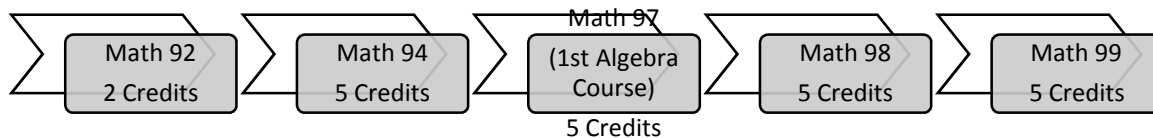
Community College D has a relatively long developmental math education sequence. Students starting at the lowest level go through one, 2-credit class followed by four, 5-credit classes

before reaching the college level. In contrast to recommendations in much of the literature that suggests shortening course sequences, several years ago this college split what was previously two courses into three courses. When these curriculum changes were made no content was added, instead the arrangement of topics was somewhat reordered and the pace of coverage of topics was slowed. According to a program administrator these changes were “amazingly controversial,” not because faculty disagreed on the three course model, in fact the longer sequence seemed to be embraced by faculty, but more because of the rearrangement of topics. The decision to have this long sequence was not made because of any policy or student success research but because faculty felt that the longer sequence was needed and appropriate to get students to the college level.

However, despite this long sequence, the majority of students place into the college’s Math 97 or 98 course (two or three levels below the college level). A recent analysis of data motivated by the college’s participation in the Achieving the Dream initiative has revealed that only a small group of students, less than 100 per quarter, are enrolled in Math 92 or 94 which are four and five levels, respectively, below the college level. In general, faculty felt that this course sequence is appropriate: one said that, “There is a huge leap between the beginning of Math 97 to the end of Math 99. In Math 97 students are clueless as to how to write math but by the time they get to college level, they are really ready to take college math.” Another faculty member commented that the split into three classes (from the previous two) allowed a lot of breadth and depth of material to be covered and the time for students to “take a breath.” However, faculty did realize that this long sequence was not optimal for all students. Faculty are now working on the development of a shorter sequence with less algebra for students who are not pursuing STEM

majors in order to alleviate what one instructor described as “non-STEM students’ decades of suffering.”

Figure 3. Math Developmental Education Course Sequence at College D



Assessment

Another change that faculty were actively working on is a new placement test. The college is one of only a small handful in the state to use a homegrown faculty developed assessment test aligned to their curriculum in lieu of the Accuplacer or COMPASS standardized tests used nationally and in a majority of colleges in Washington. The exam in place at this community college was developed by faculty but has never been validated. Faculty are now developing a new placement test and also experimenting with transcript review for placement. Students from every high school in the county are eligible to take part in transcript evaluation for placement versus placement by the assessment test and about 100 students have been placed through transcript evaluation so far. The majority of these students have been able to place into Math 141, the first calculus class. By placement test, a student may place into Math 141 but could be placed much lower. Also, motivated by Achieving the Dream, the college is following students who were placed by transcript to learn about their outcomes. The college is working to scale the transcript placement effort to a larger population of students. However, like every college using this method, transcript review for placement is only available to students who are very recent high school graduates. The assumption is that math skills are quickly forgotten and

students who have been out of high school for a longer period of time do not retain their math knowledge.

Large scale reform efforts: Achieving the Dream and the Student Achievement Initiative

Unlike the other two colleges in this study, college D is an active participant in the Achieving the Dream effort. Achieving the Dream (ATD) emphasizes data collection and analysis and data driven decisions and provides expert coaches, often higher education faculty members, professional researchers, or policy experts to advise programs on recommended changes and their implementation. In math, college administrators and faculty reported ATD coaches to have provided “lots of impetus” for changes such as mandatory placement tests for incoming students but also development of the new assessment system involving placement via high school transcript evaluation. In contrast, administrators reported the state Student Achievement Initiative (SAI) to have “not much credibility” and reported that they and faculty members did not entirely understand how points were accumulated and subsequent funding awarded and believed that some colleges had figured out how to “game the system.” They therefore believed that SAI lacked the campus buy-in to be a real change agent.

Teaching

In this math program faculty and high-level administrators were very passionate about student success. An administrator who has worked at multiple community colleges around the state and nationally said that, “Math faculty on most campuses can be pretty fatalistic but our faculty are not like that, they have learned that there are strategies and a pedagogy of being safe and comfortable, being attentive and receptive to students. I think our positive outcomes are very related to their positive attitudes.” Every staff person I spoke to relayed that the campus culture was infused with a universal commitment to student success and “a desire to really understand

student issues.” Three of the five faculty members I spoke with mentioned specific pedagogy or teaching theory books they were reading and using in their classes and talked about instilling student confidence, tenacity, and time management skills as part of the curriculum of the math class. One other piece of evidence offered up for this commitment to teaching was in regard to faculty hiring. Administrators and faculty members agreed that teaching skill is the number one factor in hiring. The Dean of the division which includes math, himself a former math faculty member, said “A PhD in math does not add value, it’s really the teaching and commitment to students we look for.”

Tutoring

One other often-mentioned and positively regarded resource on this campus is the Math Lab, a tutoring center. While instructors highly regarded the math lab, they commented that it was too far from the main math classroom space and that it was not used by the majority of students. Despite these concerns, the space is inviting and airy with large windows lined with plants, lots of computers around the perimeter, white boards for students to use, and tables grouped together. When I visited, the center seemed genuinely welcoming and full of students quietly studying in groups and individually, while a professional staff member and student tutors milled about asking if anyone needed help. Students I spoke to mention the math lab as one of the assets that had helped them pass their developmental math classes. They praised the individual tutoring and noted that instructors sometimes held office hours in the math lab. In contrast to College T, where students noted the math lab tutors were not helpful and the lab was not highly regarded by the students I spoke with, at College D, students uniformly praised the quantity and quality of tutors and professional staff.

One Morning in Developmental Math at College D

About 25 students listen attentively as the teacher stands at the white board explaining a new algebra concept. The board is soon covered with equations and drawings of what is happening mathematically on the X and Y axes. The students are peppered with questions and also asking questions of their own. Students occasionally turn to each other and discuss the concept or try to help their neighbors understand. The instructor stops for a moment and explains exactly what students will be asked to do regarding this type of problem on the upcoming exam. She checks in with students to see if they have any more questions.

When this mini-lecture is through we are about 25 minutes into class and a practice handout is provided. Suddenly it seems that what most students understood moments ago is now confusing. The instructor struggles to recover and for the next ten minutes it seems that each student is trying to make sense of the board examples and reconcile them with the handout. There is a lot of chatter among students. The instructor hits on the example of how a balloon expands and contracts when it is pulled or pushed and students seem to be able to grab on to the example. However, at least a couple of ESL students still seem to be struggling.

The class is now wrapping up and seems back on track for most students as the instructor delivers the summary of the day's content and promises to go over the concept again next class. Several hours later, we talk and she is clearly upset that the handout caused confusion. She thinks she has figured out a different way to explain the equation in practical terms for the next class. She seems genuinely determined to make sure that the students get this concept before moving on.

In the math lab the same day I see a number of students I recognize from the class. Several of them say they still don't really understand the day's content and are nervous but all are waiting for the next day of instruction to get some clarity. All sing the praises of the instructor, "she really cares, you know" two of them say they have purposefully followed this instructor from the earlier level into this higher level class. They all agree that the instructor is the most important factor to their success in math.

5.3 Case Study: Components and Perceptions of the Developmental Math Program at College AA

Student population at College AA

Administrators at College AA describe the student body as very diverse with a high ESL population and many first generation college students. The college is located in a multiracial urban area with a wide range of income levels that has long been an immigrant community.

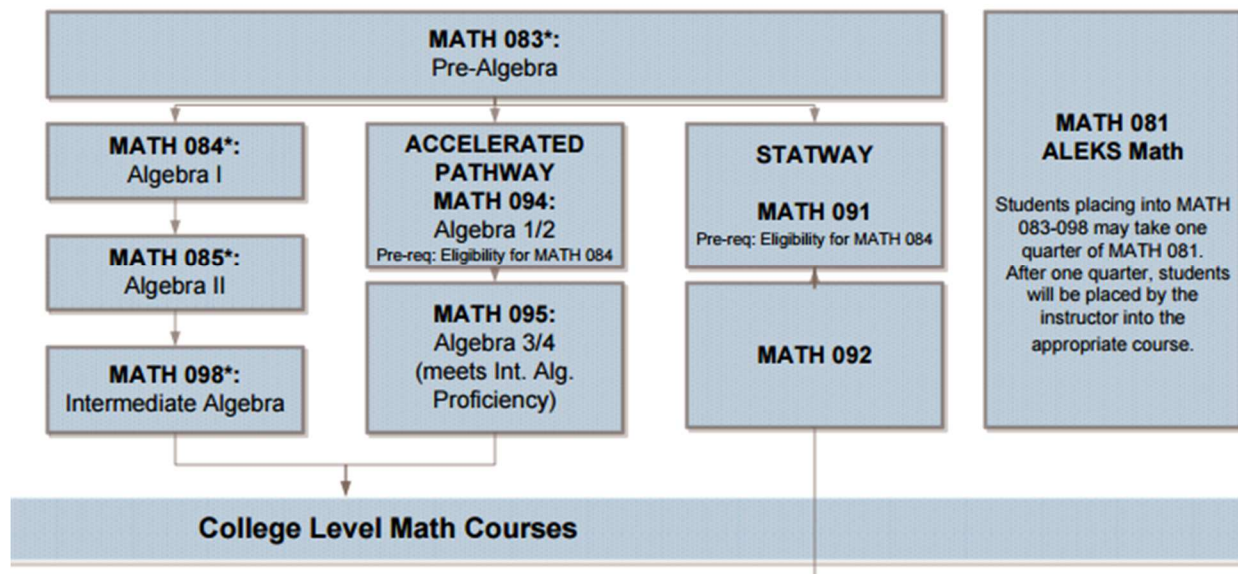
Students in College AA are heavily enrolled in GED preparation, Adult Basic Education, ESL

and Workforce Education programs. In contrast to College D where 81% of students had a college transfer intent, at College AA, just 33% of degree-seeking students intend to transfer to a four-year college. This community college is relatively small with a total annual headcount of about 7,000 students. The college enrolls about 550 students annually in all levels of math developmental education. The college mostly consists of low slung brick and concrete buildings. The buildings are surrounded by large parking lots but once one enters the central campus area it is pleasant with well-kept grounds and a central grassy area.

Developmental math organization

Despite its small size and in contrast to College D, which only had one track to move through developmental education for all students (although it is developing a second), this college has at least three different tracks and options for students to move through the developmental math sequence. The college is one of only three in the state to offer a Statway option that prepares non-STEM students for a college level statistics course. Other students can choose either a three-quarter developmental algebra sequence or an accelerated, cohort based, two-quarter algebra developmental math sequence. Another option that students who test into any level of developmental math have is the ALEKS option, which allows students to take a computer assisted modularized math course for one quarter (see flow chart). At the end of the quarter the instructor places the student into the instructor-determined appropriate next course, which could include a college-level course.

Figure 4. Math Flow Chart at College AA³²



Source: Enrollment Services Department at College AA

Teaching & Pedagogy

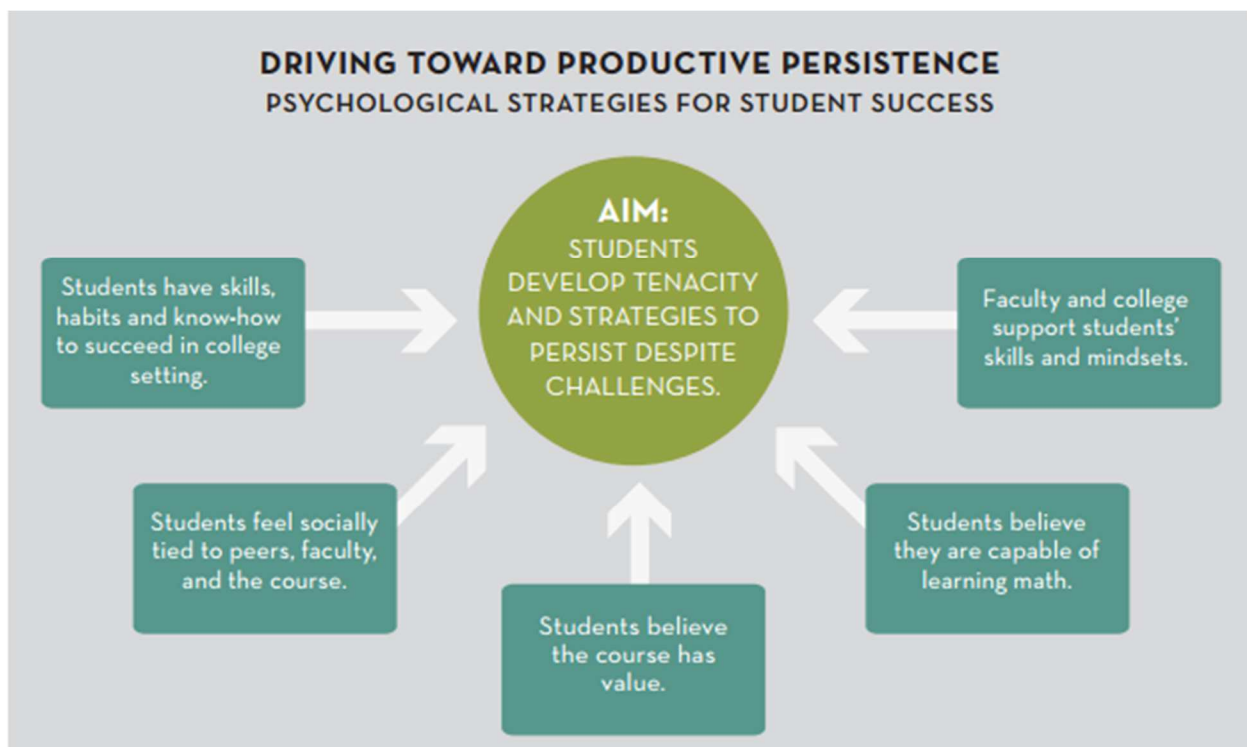
College AA has eight full-time tenured or tenure track mathematics instructors as well as six other instructors who are not on the tenure track but who do have full-time teaching loads. In addition, they have seven more instructors who are part-time with one or two courses per quarter. Everyone I spoke to attributed positive student outcomes to faculty. One said, “The faculty here are key to our good outcomes. When I first came on eight years ago there was a lot of interdepartmental tension but a lot of those people have now retired so I think our department is really strong, a united front.” Several years ago the college made the decision to hire two instructors specifically for teaching math at the developmental level. While these instructors also occasionally teach a college level course, they were able to work with other campus partners to develop the Math 94/95 cohort model accelerated pathway and they also created a tutoring space

³² Math 091 Statway Math, Math 092 Statway Math, Math 081 is computer assisted and made up of content modules.

specifically for developmental education students. The cohort model was cited as being very successful. “We believe the cohorts impart some level of confidence in the students because they know the expectations and routine, it takes some of the stress away and they know if they are successful at the first level, they can also be successful once they move on.” Instructors reported it wasn’t uncommon to see large groups of the initial 94/95 cohort stick together once they move into subsequent college level courses. The college is currently researching the relative success rates in each of these pathways.

This college was the only one I visited that offers the Statway curriculum developed by the Carnegie Foundation for the Advancement of Teaching and Learning. This model is gaining popularity nationwide but this college is one of only three in Washington to offer the curriculum. As part of nationwide training to teach this model, the Foundation has developed a theory of “Productive Persistence” (Silva and White, 2013). In the three colleges I visited this was the most fully developed theory for teaching developmental math. Although not all instructors teach the Statway model it seems that the theory has infiltrated into other developmental math courses. In the model, instructors spend time explicitly teaching study skills, and imparting confidence. For example, on the first day of class an instructor may have students read an article discussing the brain as a muscle and then lead a discussion about exercising that muscle in math. Students are given lots of positive feedback and praise and courses are designed to be practical and relevant for students. Although this model was relatively common at this community college, its use by faculty was not mandatory, and instructors are free to pick and choose none of the model or parts that will work for them. In addition, part-time instructors were not paid for attending the training, although some did so voluntarily.

Figure 5. Carnegie Foundation for Teaching and Learning Productive Persistence Driver Diagram³³



Source: Carnegie Foundation for the Advancement of Teaching and Learning

Advising

Program administrators at this college emphasized connections between the advising function of the college, math program administrators, and math faculty. Because of the three different pathways through developmental math, in addition to the ALEKS option, this program saw advising as a key partner in student success. For example, they noted that the ALEKS option takes place in a computer lab with students doing most of the work on their own. “This takes a lot of motivation and self-direction and may not be right for every student. It’s really the advisor who talks to the student to understand their strengths and desires, then they can help to get them in the right path.” Advisors and program administrators have “constant communication and

³³ From <http://www.carnegiefoundation.org/in-action/pathways-improvement-communities/productive-persistence/>

cross-talk” and meet twice a month to discuss issues and stay updated on changes on either end of the relationship.

The campus culture is described as one that embraces diversity and holistic services for students. “There are lots of supports, we assume they don’t have the information they need to succeed in higher education, things like what’s a credit, what’s a transcript, why drop instead of fail, we have to go deep and spend the time.” These two high-achieving colleges did seem to have a more student-centered view of students in developmental math than the more average achiever I visited.

5.4 Case Study: Components and Perceptions of the Developmental Math Program at College T

Description of Student Population at College T

Community College T, an average performer in my quantitative analysis, is located in a large suburb of a major city and has a large transfer population. It is a relatively large community college for Washington with an annual enrollment of about 30,000. In 2012-2013 had the largest number of transfer students to Washington baccalaureate institutions of all 28 community colleges in the state with about 1750 students transferring to a BA institution in Washington. The college has recently expanded into offering its own Bachelor’s degrees in a small number of fields and in 2012-2013 conferred 41 BA degrees. At this college 75% of all enrollments are in courses leading to a degree or certificate while 25% of enrollments are in continuing education, basic skills and ESL courses. The college is 52.7% white, 21.9% Asian and Pacific Islander and 12.5% Hispanic.³⁴ This college feels and looks a bit more like a traditional college campus than the other two colleges in the sample. There is a central fountain with some areas for gathering, the student commons area is crowded with students studying, talking in groups, and playing

³⁴ Information from the college website

music, and there are lots of colorful posters and announcements on the walls. While clearly a commuter campus surrounded by huge parking lots, of the three community colleges this one feels the most like a four-year college. The expressed goal of the college is to offer many more baccalaureate degrees and even to become a four-year institution in the future.

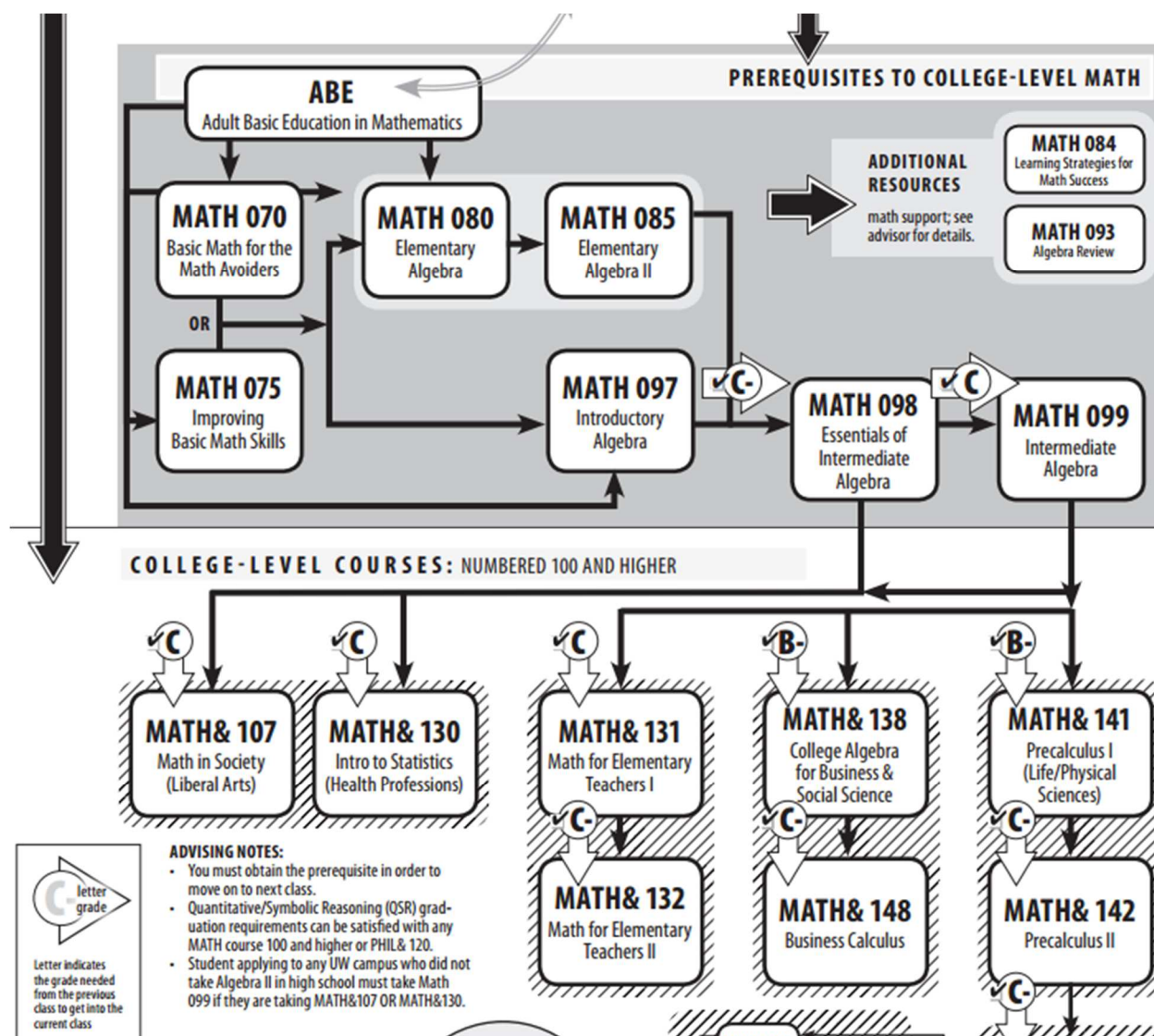
Developmental math organization

The developmental math options at this college are exhaustive and students are often referred to the math flow chart (see below) to determine which pathway is best for their specific situation. While the majority of the courses are five credits, some are variable credit computer assisted options that add review material³⁵ and one, Math 084, is a three credit supplemental course meant to be taken in conjunction with an academic math course for added instructor time and support. Students not pursuing business or STEM majors or transfer to the University of Washington can move from Math 098 (intermediate algebra I) directly to the college level. Because of the number of options available, a student pursuing a STEM major or any transfer to the University of Washington³⁶ may take as many as five, five-credit developmental courses to reach the college level (excluding optional support classes), while the shortest pathway for a student not pursuing a STEM major or transfer to the University of Washington is three courses. This type of organizational “cafeteria-style, self-service model” is specifically recommended against by researchers from the Community College Research Center who argue for more streamlined pathways to maximize student completion (Bailey, Jaggars, and Jenkins, 2015).

³⁵ Math 093 Description: Allows students to review some portion of MATH 097, 098, and 099 algebra courses. Students meet with the instructor to develop specific objectives. The course is taught using interactive software. Prerequisite: Permission of instructor.

³⁶ The University of Washington requires Math 099 (intermediate algebra II) regardless of major for transfer students.

Figure 6. Math Flow Chart at College T



Source: Advising and Transfer Center at College T

Some of the range of choices and options this program offers arises from the fact that the college has a large and diverse group of students. This math program is the largest I visited and includes 17 full-time faculty members and about 40 part-time faculty. In contrast to the other two colleges, full-time faculty members and administrators reported feeling extremely overworked and found it difficult to provide attention to student needs and administrative duties. Despite this feeling, they reported a concerted effort to build a common philosophy among a large and

diverse range of faculty opinions. Faculty reported a high value put on a high touch, nurturing environment with high expectations but also high support levels for students. The students I talked to agreed that their individual instructors met this aspiration but did not feel the holistic or student-centered model permeated the campus. In an effort to give more time to individual student needs and reduce faculty workload, the college recently committed to reducing all developmental math courses to a maximum class size of 22 students, the average had been 25.³⁷

This college does not display many of the interventions seen in the other two colleges. For example, they are not pursuing acceleration strategies beyond the class options they already have. Requirements that students wishing to apply to the nearby University of Washington need Math 099 were cited as a major factor working against changes. Faculty commented that, “Whether they make it or not, most of them want to go to UW and UW isn’t budging on that requirement.” The UW math requirement was not mentioned at the other two colleges I visited by anyone I interviewed. Administrators and faculty members at College T mostly agreed that instead of shortening the sequence or compressing it through the use of modules or software it should be slowed down to allow for more time for learning, commenting “the classes just move so much faster than in high school and students are often not prepared for that.” Yet, this goes directly counter to the emerging recommendations from research.

Assessment

The program is also not planning a new assessment strategy, although one administrator described the current COMPASS assessment as “terrible,” elaborating that reducing student performance to a single score does not work well to diagnose student needs. Another faculty member relayed that she believes the assessment test usually places students a little too high and

³⁷ The WASBCTC reports average developmental math course sizes for College AA at 21 students, College D at 27 students, and College T at 25 students http://www.WASBCTC.ctc.edu/college/d_studentfaculty.aspx

that these students tend to struggle and not be able to catch up. The main intervention contemplated at this point is the reduction in class size. They hope that by reducing faculty work load they may be able to focus more on professional development around teaching and giving students more individual attention.

Professional Development

Two rather unusual practices that have not been widely discussed in the literature around developmental math reforms are in place at this campus. First, this college emphasizes professional development opportunities including developmental math teaching circles where instructors gather to discuss teaching topics. These gatherings happen about once per month for about 1-2 hours. A recent circle featured discussion of creation of normed assignments. The topic of professional development for developmental math instructors, particularly part-time instructors, is often cited as an unknown or in need of more attention in research but few colleges appear to have much formal and ongoing professional development in place (Zachry-Rutschow & Schneider, 2011). This college pays adjunct instructors (who would otherwise not be paid) \$32/hour for attending the circles as well as other events such as “teaching squares” where instructors from different fields observe each other’s classes and discuss them. However, most other professional development opportunities are unpaid and sporadically attended by adjunct faculty.

Common Final Exams and Data Use

The other practice this math program has adopted is common final exams in the 97, 98, and 99 developmental math classes. These common finals allow faculty control over teaching methods and lesson delivery while ensuring that content remains largely the same across sections. Faculty and administrators agree that the common finals help to maintain rigor.

Administrators review student scores on the common finals each quarter and use the data in assessing instructor performance and in evaluating training needs. In the future, they plan to use the results even more as a factor in assigning class sections to high performing part-time instructors.

One Student's Experience with Developmental Math at College T

Emely is cheerful and outgoing as I enter the room where she's been waiting to talk to me. As I get settled in she says she's surprised that I want to talk to her about her math classes. She's not sure why more people are not successful as, "you'd have to be really stubborn not to take all the help they give you." She stays after class often to ask the instructor for help but she also explains that her class is different from math classes she's taken in the past. Her instructor uploads a video every day of the math content they will be discussing in class, it's usually short, somewhere between 3 and 10 minutes and she watches it a few times before class. Emely tries to arrive to class a little early because you get one extra point on the check-in assignment the instructor does at the beginning of every class. The check-in is always worth five points and meant to see if you watched the video and what you understood. You only have the first five minutes of class to complete it so it's worth getting there early. Check-ins and assignments are always handed back the next day so you don't have to wait long to see if you're doing it right. The rest of the class is then spent with review and practice. Emely says she loves this kind of structure. The instructor even has students sign up for a mobile app that reminds them of assignment dates, tests, or alerts them if there is an announcement.

Emely graduated from high school in 1994 and is a single mom. She's pursuing a degree in sonography and she exudes motivation. (I found myself really hoping she makes it.)

When she arrived to take the assessment test before beginning college she was very stressed out. She placed into Math 98 (two levels below the college level) but decided to enroll in Math 97 instead because "I'd rather really know it and succeed." After doing well in Math 97 she switched instructors to take the next class in the sequence. "It [Math 98] was really scattered, I would have failed if I hadn't had really good notes from 97 - and the content was the same except for three chapters, I don't know why those two courses aren't combined?" For the next level (where she is now) she switched back to her first instructor and has thrived.

5.5 Commonalities and Differences in Student Success Efforts in Case Study Colleges

Teaching and Professional Development

In student, faculty and administrator interviews I was struck by the constant and earnest desire to attribute student success to “good” teachers and teaching. The two more successful institutions had a smaller cadre of faculty and agreed that they had a particularly strong and unified group of math faculty with little internal struggle or disagreement.³⁸ While I didn’t find program size to be statistically associated with the outcome variables, smaller size does seem to influence a programs ability to more easily implement innovations. There are simply less faculty members to convince of change.

Instructors in the three colleges had varying individual teaching philosophies, the most common revolving around ideas of instilling grit, tenacity, and motivation in students. Some read learning theory articles with students, gave lessons on the brain, taught explicit study skills, and gave lots of praise and immediate feedback. However, most of these techniques were learned over a number of years by watching or talking to more experienced instructors or in often-times ad hoc or one-off training sessions. Training sometimes came at conferences, sometimes from far and few between opportunities to watch colleagues teach, and sometimes at formal training. These opportunities are often very limited for part-time faculty.

None of the colleges reported a formalized, developed system of integrating or providing professional development for adjunct instructors. One administrator comments that, “Hiring adjuncts is a challenge and we know that strong faculty are key . . . the faculty orientation is weak and we don’t have a fully developed faculty induction program particularly around teaching, teachers might have a great disciplinary background but little pedagogy experience.”

³⁸ I ran several models in my data to see if program size contributed to student outcomes but program size was not significant for any of my three outcomes. Despite this result it does seem that large numbers of faculty to coordinate have an impact on feelings of faculty unity and work against development of common philosophy or theory.

Every student I spoke with said that finding a good teacher is the most important factor in their success.

Despite this importance placed on teaching, when I asked about theories of teaching developmental math or whether the program had a certain philosophy underpinning its policy approach I was told in all three cases that while faculty generally share a real desire to see their students succeed there was no articulated theory beyond placing a high value on student success. Even at College AA, where the Statway curriculum involves the productive persistence model, only some instructors have embraced the theory. One other instructor said, “I don’t need it, I do my own thing.” However, student development models as described by Astin and specified further by Boylan in developmental education seem to be at the core of program pedagogy and intention even if not manifested completely in program design or rhetoric. While instructors no doubt vary widely, the faculty and students I spoke to had a wide range of experiences with courses and it seems that the “skill and drill” approach, as witnessed in Basic Skills instruction in California by Grubb (2013), is not the norm in developmental math education in Washington.

In addition, I didn’t find much evidence of a holistic approach to developmental education as described by Boylan (2002). Only the administrators at College AA talked about the importance of advising and the specific steps that the developmental math faculty and administration have taken to strengthen their relationship with student advisors. College D students and faculty emphasized their Math Lab and one faculty member at this college mentioned an “early-alert” system that allows instructors to communicate with advisors about particular students who may be having trouble in class. Outside of these examples there did not appear to be much integration or emphasis on student services for developmental education students. Chung (2005) argued that developmental education is built around largely un-

articulated theory but ultimately is based on a deficit model. While this appears to be changing with new models emphasizing student self-efficacy and motivation, I'd agree that a unified theory, or even a small scale conceptual framework, is not widely agreed upon, much less articulated, in the three programs I visited.

Student confidence and demand for developmental education

One common theme across the three campuses that both students and instructors reported was a real lack of student confidence in their math skills. Many students I spoke with, especially women, reported that they assessed into a higher-level course than where they enrolled. Students said they felt very unsure of their math skills and wanted to start over at the beginning to get a strong foundation. No students said they were surprised that they would have to take the assessment test. Not one student I spoke with did not know about the assessment test in advance of applying to college. Several said that they had prepared on their own during the period between application and taking the test, and several others said that they knew they would, "Do terrible and I wanted to start at the bottom, you know just to be really prepared because I did really bad in math in high school and hadn't taken math for so long, so I didn't care if I scored low."

This desire to start over with math was something that several students on different campuses told me. The college programs and individual instructors recognized this lack of confidence or fear of math and reported strategies such as support courses or courses where study skills and confidence topics were part of the curriculum, for example "Basic Math for the Math Avoiders" at College T. This student demand to start at the beginning in the first levels of developmental education has not been addressed in literature and should be considered in assessment and program re-design efforts.

Tension between academic rigor and acceleration

At the same time as they are trying to instill more confidence and tenacity in students, instructors also almost uniformly supported more time on task with math as opposed to shorter, compressed sequences or computer-assisted modules. Many mentioned how much faster college math goes than high school math and endorsed some curriculum overlap between classes. They emphasized the importance of “wrapping your arms around students” and expressed skepticism of modules as they currently exist in Washington in a mostly computerized format. Students also did not like the idea of computer-assisted courses. Given their low confidence levels, they felt they needed more face time with instructors to understand content. However, one limitation of the qualitative strand of this research is that I did not visit any campuses where math modules are heavily used.

In contrast to recommendations in the policy literature, faculty members would rather slow course sequences down while keeping the same amount of content rather than embracing acceleration. This tension was identified by Jaggars & Hodara (2011) who described the desire to encourage acceleration and ultimately completion working against the backdrop of the desire to maintain academic rigor. In the three colleges I visited college faculty are clearly struggling with this issue.

Data use in isolation

Each administrator in charge of math seemed to be examining their own pass rates in individual courses and expressed desire for more data to help them make decisions. At College T, administrators knew pass rates for every instructor and, because of common finals, knew which instructors’ students achieved the highest scores. They could track such outcomes across quarters and this information is used when scheduling instructors. College D administrators

know what percentage of incoming students start in each level of developmental math and what percentage pass the developmental sequence. Faculty members also reported that they had recently felt more scrutiny of their individual course outcomes.

At College AA, administrators know the pass rates for each of the different tracks of developmental math. However, only at College D did institutional research seem to be integral to data collection and analysis. Achieving the Dream was cited as the impetus for more integrated data use. At the other colleges the program administrators and deans were pulling their own data from the system or using data easily available to them, such as average scores on common final exams, rather than getting actionable data from the institutional research office. Institutional research offices at College AA and College T did not appear to be well-integrated into the day to day decision making of the administrators in charge of developmental math programs. This lack of integration may be less than optimal for promoting data driven decision making and ultimately student success.

In all three colleges full-time faculty, and administrators had kept abreast of developmental education research and policy recommendations and knew of the large national reform efforts, as well as state and district or local efforts to improve developmental education success rates. The two high performing institutions in my sample were trying several interventions recommended by research and monitoring their efforts with data (although in a somewhat ad-hoc fashion). The more average performer was not engaging in many of the policy reform efforts, although they were reducing class sizes and emphasizing professional development. They attributed the lack of new approaches to being overworked, and having a large and diverse group of faculty to convince of any new interventions. More recent research has begun to describe and address the implementation challenges such as these that are often

presented in change efforts in math developmental education programs (Edgecombe, Cormier, Bickerstaff, & Barragan, 2013).

However, despite policy changes and experimentation with new strategies, every student, faculty member, and administrator I spoke with agreed that teachers and teaching are at the core of successful student progress through the developmental math sequence. Every person I spoke with on the three campuses appeared dedicated to student success. All of them were undertaking a difficult job, felt increased outside scrutiny of their work, and genuinely wanted to help students succeed. This attention that campus leaders and faculty paid to teachers, teaching, and pedagogy has been addressed only in small pockets in current reform efforts and largely leaves part-time faculty, who teach many if not most, developmental courses out of decision-making and training, which may ultimately limit the success of reform efforts.

Chapter 6:

Integrating and Interpreting Mixed Methods Findings

This sequential, explanatory research design covers a relatively large area of inquiry. The quantitative research investigates college policy and practice factors influencing students' probability of passing the developmental math sequence, passing a first college level math class and highest level of education achieved. With Student Achievement Initiative (SAI) data from 2011-2014 and other data sources, the analyses investigated the role of policy [?] and program policies [?] in explaining variance in math and educational success rates, after accounting for individual characteristics. The qualitative strand of this research reported findings of interviews conducted with stakeholders in three colleges to uncover promising practices in colleges influencing or inhibiting students' success in developmental math, obtain more detailed understanding of policy design and implementation (including challenges), and investigate how students, faculty, and program administrators perceive new innovations or current practice in relation to student success.

From the quantitative analysis, I learned that higher starting level in developmental education, higher student SES, and higher levels of prior education, were student factors significantly positively associated with passing the developmental math sequence of courses. Being an underrepresented minority student was significantly negatively associated with success in passing the developmental math sequence. With these significant student level variables controlled, the policy variables associated with avoiding as many levels of developmental education as possible given the student's ability (i.e. alternative placement and an assessment test

preparation course) were not significant in the presence of all other predictors, but did show positive associations with the outcome variable. The same HGLM analysis with the outcome of whether the student passed a college level math course after completing the developmental sequence revealed that a higher student start level, and higher prior education, were significantly positively associated with this outcome, while again underrepresented minority status was negatively associated with student success. With these variables accounted for, fewer developmental math courses in a college's sequence was significantly associated with student probability of passing a college level math course, even in the presence of all other predictor variables. This association implies that fewer math courses in a developmental education sequence do not leave students unprepared for college level math.

I further learned that colleges exhibiting “innovative” approaches, such as employing some developmental course avoidance strategies, some acceleration strategies, and a shorter course sequence to reach the college entry level were significantly more successful in terms of the two student outcomes described, than colleges exhibiting a more business-as-usual approach. From the quantitative analysis I also learned that, at least for my sample population, college attended did not influence the highest education level a student attained, after controlling for student background characteristics. In other words, colleges did not seem to vary in their contribution to educational attainment, a finding that calls into question whether and which college policy and practice levers can affect student performance by this measure and the efficacy of pay for performance efforts.

These findings led me to further investigate developmental math practices through the college case studies in order to learn about assessment and course sequence practices in two colleges with above-average student success rates, compared to one with average rates. I was

also interested in learning about what college administrators, faculty members, and students believe are important factors in student success and use their insights to contextualize and complement previous research findings and my own statistical findings.

This chapter summarizes the conclusions from this mixed-methods dissertation, provides an overview of the contribution of these findings to the literature, considers implications for practitioners, describes some unanswered questions and limitations, and offers suggestions for future research directions.

6.1 Conclusions from the Mixed Methods Analysis

Neither the student level variables nor the program level policy and practice factors I examine in my quantitative analysis do a particularly good job at predicting student success in math developmental education on their own. However, they do point in some promising directions (e.g. the further investigation and development of prior education transcript review for placement) and also point to the importance of investigating other factors not usually considered in higher education research but more common in K-12 literature (e.g. the existence of culturally relevant pedagogy) to account for more of the variance in outcomes and also to point to directions for reforms.

In my analysis, only four colleges in Washington had systems for alternative placement in place in the 2011-2014 time frame but several others are now developing and piloting such systems. I found that alternative placement, while not significantly uniquely predictive of student success in terms of probability of passing the developmental math sequence in the presence of all other predictors, was associated with higher rates of student success. In the alternative placement method employing transcript review to determine in which course level a student can reasonably hope to succeed, faculty members or advisors assess a student's grades in high school math and

overall high school GPA. Cross-walks of high school course content against college course content enable staff to determine where overlaps or gaps exist. Course grades and GPA may also reveal information about a student's motivation and study habits. Researchers have found transcript analysis to be a better predictor of college success in math than relying solely on a standardized math assessment test score (see for example, Belfield & Crosta, 2012), and in my analysis this avenue seems promising for future development, at least for recent high school graduates.

To address the majority of Washington developmental education math students who are not recent high school graduates, another avoidance (of unnecessary developmental courses) strategy I found to be associated with success were mini courses students take before the standardized assessment exam that review math topics. In my analysis, many colleges in Washington linked a small, on-line tutorial of math topics from their advising websites but six colleges offered more intensive preparation courses taught by college faculty. I was curious to learn more about this strategy, which has not been widely discussed in the literature.

None of the colleges where I performed my case studies offered this option and when I questioned administrators and faculty members it seemed there was not a great deal of enthusiasm. These types of strategies require considerable collaboration between math faculty, who would presumably develop and ultimately teach the preparatory course, and advisors, who would recruit and refer students to enroll. Administrators at my case study colleges doubted there would be large numbers of students who would invest to take these non-credit courses before the assessment. They also wondered where the funding to offer such courses would come from. Despite these administrative hurdles, it seems that pre-assessment review courses might be worthy of further investigation to see if they are a viable avoidance strategy as their presence did

seem to be positively associated (although not uniquely significantly predictive in the multilevel model) with student probability of passing the precollege math sequence in my analysis.

Having a smaller number of developmental education courses before the college level at a college was significantly associated with the probability of passing a college-level math course. It seems then, that these shorter developmental course sequences do not leave students unprepared for college level math and, in fact, might help them obtain greater math proficiency than long sequences of developmental math. On campus though, I found that, while developing some shorter tracks and accelerated pathways for students was an idea gaining popularity, many (indeed all) math faculty I spoke with had real concerns about students' math understanding and wished to see students spend more time with math rather than less time. Faculty recognized that an algebra pathway might not be needed or even optimal for all students but, for those that do need an algebra pathway because of their eventual college or career goals, faculty desired to slow that particular pathway down rather than speed it up. This tension between what faculty see as maintaining rigor and encouraging the greatest possible rates of completion has been described by previous research and I found, at least in colleges with high rates of student transfer, the concern is real and unresolved.

Finally, I examined whether an empirical typology of developmental math programs components could be developed that could be associated with either positive or negative student outcomes. Through a principal components analysis two empirically grounded typologies were developed. The first class of programs was the most common and exists in colleges with a comparatively high level of external commitment to the developmental education mission. These colleges are more likely to participate in Achieving the Dream and have developmental education embedded in their college mission statement or core themes. These colleges have few,

if any, avoidance strategies, a smaller student to faculty ratio, few, if any, acceleration strategies, and a higher number of developmental courses that a student must pass to reach the college level. I consider these programs to be more traditional in their approach to developmental education.

In contrast, the more innovative programs demonstrated in the PCA some avoidance strategies, some acceleration strategies, and a relatively shorter course sequence to achieve the college level. These colleges also have slightly higher student to faculty ratios and show less (at least rhetorical) commitment to developmental education in their mission language. Logistic regression with these two typologies as the predictor variables (and controlling for student characteristics) revealed that programs with a more innovative approach do seem to be significantly benefiting students. Innovative colleges had a 21% higher success rate in passing precollege math and a 6% higher success rate in passing a college level math course, with both differences significant at the $p < .05$ level. This suggests that more institutions should consider adopting some of these reform efforts.

The last outcome variable I examined in the multilevel statistical analysis was whether college attended was associated with momentum points earned (i.e. highest education attained) by students. After controlling for student background characteristics, I found no association between college attended and highest education level attained by students over the three years examined for this sample. The theory that community college programmatic or policy variables, or even changeable institutional characteristics, contribute much to explaining overall student educational attainment remains unproven. Given the increasingly large amounts of funding tied to institutional performance measurement schemes, more research should be done to discover if and how colleges can influence overall educational attainment outcomes as well as how they are measured.

From my qualitative research on campuses, it seems that the Student Achievement Initiative (Washington's version of pay for colleges tied to student performance on indicators) does not seem well understood. Administrators had a much better grasp of the point system that awards funding for students reaching a series of milestones than did faculty, but even they did not know where their campus ranked in comparison to other colleges, or what strategies more successful colleges employed. Unfortunately, SAI measures do not take into account any student background characteristics, meaning that colleges with less disadvantaged populations might have a built-in advantage in accumulating points, and therefore in funding.

All interviewees across all colleges indicated that instructors are key to the student success equation but are often overlooked by the literature. In this analysis I found it very hard to get any data on instructor years of experience, pay rates across campuses, hiring expectations, training, percentage of full-time versus part-time faculty teaching developmental math, etc. I also found that, while quality of instructors was considered key, there was not much overarching theory that differentiated the set of "good" instructors from the not so good, or how to turn the latter into the former. Also, while some part-time instructors are no doubt excellent instructors, they were often left out of meetings, trainings, and opportunities for sharing pedagogy and teaching methods. What effective full-time instructors do in the classroom to help students succeed remained somewhat mysterious and unexplained, and this was even truer for good adjunct instructors.

Many unanswered questions remain regarding how community colleges can best address funding limitations, increasing accountability for improved developmental education student success, and effective provision of differentiated support for math success for different student groups that may have varying objectives and intentions. One of the most pressing challenges

faced by colleges is how to implement and adapt time-and labor-intensive pilot initiatives, such as alternative placement through transcript review, for broad impact among a larger student population.

Further empirical research would be useful on college-level practices, including instructional practices, that close gaps in math achievement between student groups traditionally more successful with developmental math and those not performing as well. While I did not address student achievement gaps across subgroups as part of this research project, I did find consistently lower success rates in developmental math among underrepresented minority students and specific strategies aimed at this population have not been widely addressed by research.

6.2 Contributions and Limitations

The strength of the quantitative strand of inquiry reported here lies in its use of a large and recent sample representing students at each community college in Washington to determine how variation in students' success in math is associated with college policy and practice variables, *net of* student variables. However, the study also had challenges in data availability, definition and measurement. Data limitations include: a lack of desirable variables that would have more fully described student characteristics, in particular gender and full-time or part-time status, and student intent; lack of specific, annual measures of college policies for the appropriate period; and the lack of measures of policy implementation strength. It should be noted though that the inability to measure these variables likely reduced the strength of relationships found by my analysis, i.e., so mine are likely conservative estimates.

The strength of the qualitative analysis here lies in its findings about specifics of college practices that are being developed to improve developmental education math success,

particularly where the findings provide confirming or disconfirming evidence to quantitative findings, or a more nuanced perspective on quantitative findings. Unfortunately, this data is limited by the relatively small numbers of people with whom I was able to speak. I was unable to gain access to students at College AA so my description of theories of developmental education, policies affecting students, and classroom practice at this college are unconfirmed by students. In addition, I was only able to interview “successful” students. Finding students to interview who had been unsuccessful would be a challenge because these students are likely no longer enrolled in math or in the community college. In an effort to get a sense of their transitions from one level to the next and to speak with students who had significant experience with the math developmental education program, I intentionally sampled students who had already passed one precollege course. However, these students’ experiences are probably, on the whole, more positive than unsuccessful students and by emphasizing successful practices I may have missed policies or practices students find particularly detrimental.

Nevertheless, the patterns found in the quantitative and qualitative analyses are broadly consistent. The contrasts between high performing and average colleges on developmental math outcomes are instructive in learning about promising practices and challenges operating in diverse colleges with respect to the development of math pathways, data used to inform decision making, and faculty insights and perspectives.

Another limitation built into the design is that the multi-level analyses in the quantitative strand do not support any true causal claims regarding the advantage to success in developmental or college-level math from enrolling in community colleges with certain policies. Causality can only be established with experimental and certain quasi-experimental research designs (Shadish, Cook, & Campbell, 2002) rather than from secondary analyses of data such as was possible here.

Instead, the analyses here report on factors and policies statistically associated with community college students' outcomes utilizing the policy and practice data that I gathered and assembled from state policy experts and community college sources, and the SAI data on student characteristics and outcomes from the WASBCTC. Case studies of community colleges performing above-average and about average with respect to students' success in math offered insights into policy development and implementation issues regarding how to meet diverse community college students' needs and expectations. Again, the findings from the two strands were broadly consistent.

The qualitative research offers a grounded, practice-rich understanding of promising (and also those apparently not as constructive or effective) practices and policies that cannot be obtained from the quantitative analyses. Mixed-methods studies such as this are rare, and offer complementary information to leaders in community colleges, policy makers, and researchers for improving student success in developmental math. Both study strands offer insight regarding how students' decisions, opportunities and performance interact with community colleges' policy and practice. In this way, the quantitative and qualitative analyses offer complementary findings regarding strategies, policies, and factors influencing potential improvements to students' success in developmental math and, ultimately, in their quest for a college credential.

Appendix A. Community College Program Policy and Practice¹

College	Enrollment ²	Proportion URM	Student to Faculty Ratio in Dev Ed Math ³	Minimum Number of Courses to Complete Dev Ed Sequence ⁴	Modules	Diff. Tracks	Pre Assessment Test Math Review Course	Statway	Dev Ed Appears in Mission or Core Themes	Contextual Instruction	Mandatory Orientation or First Year Experience	College Level Instructor also Teach Dev Math	Alt Placement	ATD
A	432	0.22	22.03	5	Yes	No	No	No	No	No	No	Yes	No	No
B	743	0.12	22.6	3	No	Yes	No	No	Yes	No	No	Yes	No	No
C	1,311	0.17	19.23	5	No	No	No	No	No	No	Yes	Yes	No	Yes
D	896	0.13	27.66	4	No	No	No	No	No	Yes	Yes	Yes	No	Yes
E	651	0.13	18.39	6	Yes	No	Yes	No	No	Yes	No	Yes	No	Yes
F	328	0.16	20.72	2	No	Yes	No	No	No	No	No	Yes	No	No
G	585	0.18	24.08	4	No	Yes	No	No	No	No	No	No	No	Yes
H	305	0.11	24.41	3	Yes	Yes	No	No	Yes	No	No	No	No	No
I	714	0.12	28.77	4	Yes	No	No	No	Yes	No	Yes	Yes	No	Yes
J	814	0.11	20.89	4	Yes	No	No	No	No	No	No	Yes	No	Yes
K	1,577	0.32	27.26	4	No	No	No	Yes	Yes	No	No	No	Yes	Yes
L	272	0.44	40.62	4	No	No	No	No	No	No	Yes	No	No	Yes
M	240	0.11	23.25	4	No	No	No	No	No	Yes	Yes	Yes	No	Yes
N	268	0.14	25.58	2	No	Yes	Yes	No	No	No	Yes	Yes	Yes	No
O	861	0.23	26.39	4	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
P	463	0.21	20.09	6	Yes	No	No	No	No	Yes	Yes	Yes	No	Yes
Q	730	0.27	26.87	2	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
R	958	0.15	23.34	3	No	No	No	No	No	No	No	No	No	No
S	490	0.38	23.95	3	No	Yes	Yes	No	Yes	No	Yes	Yes	No	No
T	799	0.16	24.96	4	Yes	Yes	No	No	No	No	Yes	Yes	No	No
U	772	0.13	27.33	4	No	No	Yes	No	No	No	Yes	Yes	No	No
V	1,385	0.45	28	3	No	No	No	No	No	No	Yes	Yes	No	Yes
W	809	0.27	27.58	3	No	No	No	No	Yes	No	No	Yes	No	Yes
X	530	0.19	25.17	3	Yes	Yes	No	No	No	Yes	No	Yes	No	No
Y	481	0.35	22.5	4	No	No	No	No	Yes	No	No	No	No	No
Z	1,207	0.18	30.28	4	No	No	No	No	Yes	No	Yes	Yes	No	Yes
AA	293	0.29	20.57	3	No	Yes	No	Yes	Yes	No	Yes	Yes	No	No
BB	2,020	0.15	26.27	3	No	Yes	Yes	No	No	No	Yes	Yes	No	No

¹ Policy measures based on whether policy was widely implemented at scale by end of study, spring quarter 2014

² Total enrollment in dev. math courses 2,3, and 4 levels below the college level at the start of the study, fall quarter 2011

³ Data from State Board for Community and Technical Colleges available at

http://www.sbctc.ctc.edu/college/d_studentfaculty.aspx

⁴ Minimum number of courses college indicates student needs to pass in dev ed sequence to enter Math 107, a common course, as of spring 2014

Appendix B

State Policy Expert Interview (State ABE Director, Director of Core to College, Associate Director of SBCTC)

Thanks very much for your time and expertise. As you may know, I worked in the WA community college system as a faculty member and administrator for a number of years. I'm now working on my PhD at the UW and writing a dissertation on developmental math in the state CC system. Since I've been out of the system for a while, I am talking to you to learn more about what's happening in developmental education math programs in Washington State community colleges and get an overview of the variation, reforms and innovations happening now.

1. Can you tell me a bit about what current developmental math programs look like for the majority of students? Probe: About what percentage of students would you say are being taught in the more traditional classes and course sequences vs. some new model? (i.e. accelerated classes, modularization, flipped classes, etc.).
2. How varied do you perceive programs to be across institutions? Not just in terms of innovations but all sorts of policy variables like placement practices, faculty experience and training, student support services, length or content of sequences?
3. Can you give me an overview of current reforms or innovations being driven by the state legislature or the SBCTC?
4. Are there other reforms or innovations that are being driven more by local community colleges? *Follow-up* – So from the last two questions let me summarize what you think is happening right now in the college-system regarding reforms or innovations – do I have it right?
5. How varied are the reforms or innovations being tried? Probe: Are some colleges much more eager to try new ideas?
6. Can you describe one or two colleges that you believe are forward thinking in their approach? What about a college or two that is more traditional? Probe: What characteristics do you think make them more innovative or more traditional?
7. What do you think are the most important or promising reforms? Probe: What mechanisms do you think are most important for strengthening developmental education programs in math. Why?
8. My intent is to do case studies of three institutions, I'm looking for a typical program and a couple that might be more high performers – programs that have tried different things successfully. If you were going to do in-depth case studies at two or three institutions of their developmental education math programs, what programs do you think might be interesting to look at? Why?
9. As opposed to a few years ago before the big emphasis on developmental math, are programs across all of the institutions moving to a more standardized approach or have all of the innovations and reforms being tried created more variation across programs?
10. If you were thinking about what program level variables might be important to student success in developmental math education programs, what variables or factors would you want to look at?
11. Is there anything else you think would be important to know if I'm looking at college/program variation in student outcomes?

Appendix C

Program administrator interview (Deans, Associate Deans or Program Directors)

Thanks very much for your time and expertise. As you may know, I worked in the community college system as a faculty member and administrator for a number of years. I'm now working on my PhD at the UW and writing a dissertation on developmental math in the state CC system and I'm looking more in depth at few of the colleges to understand how developmental math programs operate on the ground.

1. What is the definition of developmental education at your college?
2. Can you give me an overview of the developmental math program here at X college?
Probe: How do students move through the program, what does the organization of the program look like in terms of administration, How much autonomy do you as an individual administrator member have to make program organization decisions? How much autonomy does the program have overall vs. the college administration or SBCTC?
3. Is your college experimenting with any new reforms or innovations? Which ones? Probe: How long have interventions been in place, what have been implementation challenges, how widespread are reforms? How did you implement them?
4. What does the typical developmental math classroom look like in terms of instructional delivery, pedagogy, and technology?
5. What is the typical level and type of experience of part-time vs. full-time instructors within the program?
6. What are required qualifications to teach developmental math?
7. What training is provided to instructors? Do instructors collaborate in any organized way?
8. How is the developmental program organized? How do you assure that course levels are aligned and that dev ed is aligned with college level course work?

Thank you!

Appendix D

Faculty interview protocol

Thanks very much for your time and expertise. As you may know, I worked in the community college system as a faculty member and administrator for a number of years. I'm now working on my PhD at the UW and writing a dissertation on developmental math in the state CC system. As part of the dissertation I'm looking more in depth at a few of the colleges to understand how developmental math programs operate on the ground.

1. Can you give me an overview of the developmental math program here at X college?
Probe: How do students move through the program, what does the organization of the program look like in terms of administration, How much autonomy do you as an individual faculty member have to make curricular or pedagogy decisions?
2. What does the typical developmental math classroom look like in terms of instructional delivery, pedagogy, and technology?
3. As you probably know, developmental education has gotten a lot more attention lately, have you felt that focus at all in your work? How?
4. Is the college trying any new math interventions or reforms? What are they? How were you made aware of them and trained or prepared? Follow up: How long have reforms been ongoing, what have been the challenges with implementation, how widespread are they within the program?
5. Some researchers have suggested best practices such as making sure that adjunct faculty are integrated within the college community and also into a community of developmental education practitioners and that there is collaboration among faculty. To what extent do you see that here? Probe: Can you give me an example of such practices?
6. Do you ever do any peer review or coaching of teaching? If so, can you tell me a little about who did it, what it looked like?
7. Can you tell me a little about your personal philosophy or view on teaching dev ed math courses? Follow-up: How did you become a developmental education math teacher? Is your path typical in this college?
8. When you think about program policy or practices that might be important for student success, what comes to mind? Are these ideas in play here?
9. Where do you think math developmental education at your campus excels? Where is there room for improvement?

Thank you!

Appendix E.

Student Interview

I am talking to you to learn more about what's happening in developmental education math programs in Washington State community colleges. I'm interested in hearing about your experiences in your math classes at this college. I am a doctoral student at UW and this is part of my dissertation research. I have been a CC faculty member.

1. How did you find out what math class to enroll in? Probe: Did you know you would have to take an assessment test? Did you try to prepare for it at all or did the college try to prepare you?
2. Can you describe for me a typical day in your math class? Is this similar to previous course if any?
3. When you moved from the last level you were in to this level did you feel like the curriculum was aligned?
4. Do you have an advisor? How often do you see him/her?
5. Do you ever use tutoring services? Follow-up: has your math instructor ever suggested that you use them or that anyone in the class could use them?
6. If you're thinking about things the college does that might help you succeed in your math classes what comes to mind?
7. Are there any things the college helped you with that helped you pass your first math class?
8. What else do you think I should know about your math classes here?

Thank you!

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