November 2019

Gaining Ground

Findings from the Dana Center Mathematics Pathways Impact Study

Elizabeth Zachry Rutschow, Susan Sepanik, Victoria Deitch, Julia Raufman, Dominique Dukes, and Adnan Moussa

CAPR

CENTER FOR THE ANALYSIS OF POSTSECONDARY READINESS

Gaining Ground

Findings from the Dana Center Mathematics Pathways Impact Study

Elizabeth Zachry Rutschow
MDRC

Susan Sepanik
MDRC

Victoria Deitch
MDRC

Julia Raufman
Community College Research Center

Dominique Dukes
MDRC

Adnan Moussa
Community College Research Center

November 2019

The Center for the Analysis of Postsecondary Readiness (CAPR) is a partnership of research scholars led by the Community College Research Center, Teachers College, Columbia University, and MDRC. The research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305C140007 to Teachers College, Columbia University. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education. For more information about CAPR, visit postsecondaryreadiness.org.

The research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305C140007 to Teachers College, Columbia University. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.

Dissemination of MDRC publications is supported by the following organizations and individuals that help finance MDRC's public policy outreach and expanding efforts to communicate the results and implications of our work to policymakers, practitioners, and others: The Annie E. Casey Foundation, Arnold Ventures, Charles and Lynn Schusterman Family Foundation, The Edna McConnell Clark Foundation, Ford Foundation, The George Gund Foundation, Daniel and Corinne Goldman, The Harry and Jeanette Weinberg Foundation, Inc., The JPB Foundation, The Joyce Foundation, The Kresge Foundation, and Sandler Foundation.

In addition, earnings from the MDRC Endowment help sustain our dissemination efforts. Contributors to the MDRC Endowment include Alcoa Foundation, The Ambrose Monell Foundation, Anheuser-Busch Foundation, Bristol-Myers Squibb Foundation, Charles Stewart Mott Foundation, Ford Foundation, The George Gund Foundation, The Grable Foundation, The Lizabeth and Frank Newman Charitable Foundation, The New York Times Company Foundation, Jan Nicholson, Paul H. O'Neill Charitable Foundation, John S. Reed, Sandler Foundation, and The Stupski Family Fund, as well as other individual contributors.

For more information about CAPR, visit postsecondaryreadiness.org.

For information about MDRC and copies of our publications, see our website: www.mdrc.org.

Overview

Analyses of literacy and numeracy levels worldwide by the Organisation for Economic Cooperation and Development suggest that the U.S. population has one of the lowest numeracy levels among industrialized nations. Although education leaders and math experts have recognized this problem for years and sought to address it, many people in the United States continue to struggle with learning math. While postsecondary schools have sought to prepare incoming students for college-level math with a curriculum known as developmental or remedial math, however, the problem has persisted. Schools require large proportions of entering college students to take these courses, which can take multiple semesters to complete. And far too few of these students ever successfully complete them. As a result, many practitioners and policymakers focused on improving developmental math courses by shortening the course sequences that students are required to take or streamlining the content in an effort to get students into college-level courses more quickly. Nevertheless, to date, few reforms have focused on changing the *type* of math that students learn and *how* they learn it.

To meet this challenge, the Charles A. Dana Center at the University of Texas at Austin developed the Dana Center Math Pathways (DCMP), which diversifies the math course content that students take so it better aligns with their career interests. The Dana Center also developed curricula for three math pathways, which revise the content and instruction in developmental and college-level math classes while also streamlining the typical two-semester developmental math series into one semester. Starting in 2014, researchers from the Center for the Analysis of Postsecondary Readiness — a partnership between the Community College Research Center at Teachers College, Columbia University, and MDRC, as well as research scholars from several universities — began studying the DCMP curricular models using a randomized controlled trial at four Texas community colleges. This report analyzes the implementation of the curricular models at the institutional and classroom levels and the contrast of the new models with traditional developmental and college-level math classes, the impact of the DCMP on students' academic outcomes for up to four semesters, and the DCMP's costs compared with colleges' standard course pathways.

Overall, the study found that the four Texas colleges revised many institutional policies, enabling them to implement the DCMP and offer DCMP courses to many more students than was done before the study. Virtually all DCMP developmental and college-level courses remained faithful to the DCMP's revised curricular and pedagogical design, which contrasted sharply with colleges' standard developmental course offerings and college-level algebra courses. However, colleges experienced some challenges, such as targeting all students who were eligible for the DCMP and aligning the new math policies with requirements of four-year colleges to which their students were likely to transfer.

After three semesters, the DCMP had a positive impact on students' completion of the developmental math sequence, increasing their likelihood of taking and passing college-level math and the number of math credits earned. Researchers also saw a small impact on early cohorts' attainment of a certificate. They found no impacts on overall credit accumulation or on receipt of an associate's degree or transfer to a four-year college, although it was unlikely to see such impacts in so short a time. The study found that both start-up costs and net ongoing direct costs to the colleges from the DCMP are fairly low, although the colleges also received many supports from the Dana Center that are not included in these estimates.

Contents

Appendix

List of Exhibits

Table

Figure

Figure (continued)

Box

Acknowledgments

We would like to thank the staff at the Charles A. Dana Center at University of Texas at Austin for their support of the evaluation. They were instrumental in helping us at all stages. We would also like to thank the faculty, staff, and administrators at the four Texas community colleges who partnered with us for the evaluation: Brookhaven College, Eastfield College, El Paso Community College, and Trinity Valley Community College. In addition, we are grateful for the contributions of all the students who shared their experiences with us through the survey and focus groups.

We greatly appreciate the work of the staff from the Center for the Analysis of Postsecondary Readiness who helped support our work with the colleges and the research study over the past five years. We would especially like to thank the following individuals: Evan Weissman, Elena Serna-Wallender, John Diamond, Katherine Blessing, Alissa Gardenhire, Anna Marie Ivery, Jessica Taketa, Timothy Rudd, Kayla Reiman, Janel Smalls, Sara Staszak, and Oscar Cerna of MDRC; and Tom Bailey, Nikki Edgecombe, and Octaviano Chavarín at the Community College Research Center. Leslyn Hall, a consultant for MDRC, coordinated the student survey effort, and the Temple University Institute for Survey Research conducted the student survey.

We are grateful for the many people who provided us with oral and written feedback on this report, including James Benson at the Institute of Education Sciences; Alexander Mayer, Dan Cullinan, Jennie Kaufman, Therese Leung, and Alice Tufel (MDRC); Thomas Brock, Nikki Edgecombe, Susan Bickerstaff, and Amy Mazzariello (CCRC); Vilma Mesa (University of Michigan); and Jennifer Dorsey, Connie Richardson, Amy Getz, Erica Moreno, and Martha Ellis (Dana Center). Affiong Ibok assisted in fact-checking the report. Finally, we would like to thank the Publications department at MDRC, including consultant Alice Chasan, who edited the report, and Carolyn Thomas, who prepared the report for publication.

The Authors

Executive Summary

Analyses of literacy and numeracy levels worldwide by the Organisation for Economic Cooperation and Development suggest that the U.S. population has one of the lowest numeracy levels among developed nations. Sixty-four percent of American adults are unable to use math and interpret math problems that most higher-level jobs require, and a full 30 percent can perform only basic mathematical computations such as arithmetic or solve simple one-step operations such as counting.[1] These findings reveal the critical need to improve American adults' math skills.

Even in the U.S. educational context, many people continue to struggle with learning math, and college preparatory math classes, also known as developmental or remedial math, present a particular challenge. The challenges with developmental education — and developmental math, in particular — have become well known. Large proportions of students — up to 70 percent in two-year colleges and 40 percent in four-year colleges — enter college taking developmental classes, and around half of these students never complete their developmental math requirements.[2] Studies have also shown that the methods used to teach these courses are often not aligned with the instructional methods that math experts recommend.[3] Given that developmental math can cost students and their families upward of $1 billion per year for the students who take these courses, many of whom never earn a degree, the need to improve developmental math students' success is critical.[4]

---

[1]Organisation for Economic Cooperation and Development, *Key Facts About the Survey of Adult Skills (PIAAC)* (Paris, France: Organisation for Economic Cooperation and Development, n.d.); Program for the International Assessment of Adult Competencies, and Institute of Education Sciences National Center for Education Statistics, *PIAAC: What the Data Say About the Skills of U.S. Adults* (Washington, DC: National Center for Education Statistics, n.d.).

[2]Xianglei Chen, *Remedial Coursetaking at U.S. Public 2- and 4-Year Institutions: Scope, Experience, and Outcomes*, NCES 2016-405 (Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education, 2016); Thomas Bailey, Dong Wook Jeong, and Sung-Woo Cho, "Referral, Enrollment, and Completion in Developmental Education Sequences in Community Colleges," *Economics of Education Review* 29, 2 (2010): 255-270. Chen's study only looked at students who enrolled in courses rather than students referred to these courses, while the Bailey, Jeong, and Cho (2010) study analyzed developmental education referrals.

[3]James W. Stigler and James Hiebert, *The Teaching Gap: Best Ideas from the World's Teachers for Improving in the Classroom* (New York: The Free Press, 1999); James Hiebert, "What Research Says About the NCTM Standards," pages 5-23 in J. Kilpatrick, W. G. Martin, and D. Schifter (eds.), *A Research Companion to Principles And Standards For School Mathematics* (Reston, VA: National Council of Teachers of Mathematics, 2003); Karen B. Givvin, James W. Stigler, and Belinda J. Thompson, "What Community College Developmental Mathematics Students Understand About Mathematics, Part 2: The Interviews," *MathAMATYC Educator* 2, 3 (2011); James W. Stigler, Karen B. Givvin, and Belinda J. Thompson, "What Community College Developmental Mathematics Students Understand About Mathematics," *MathAMATYC Educator* 1, 3 (2010): 4-16; W. Norton Grubb, *Basic Skills Education in Community Colleges: Inside and Outside of Classrooms* (New York: Routledge, 2013).

[4]Elisabeth A. Barnett, Peter Bergman, Elizabeth Kopko, Vikash Reddy, Clive R. Belfield, and Susha Roy, *Multiple Measures Placement Using Data Analytics: An Implementation and Early Impacts Report* (New York: Center for the Analysis of Postsecondary Readiness, 2018); Laura Jimenez, Scott Sargrad, Jessica Morales, and

With these troubling statistics in mind, many colleges, systems, and states have taken bold action to reform developmental education, making changes to everything from the way that they assess students' college readiness to the structure and sequencing of developmental education courses — and many reforms are showing promising results in rigorous studies.[5] Nevertheless, few of these changes have sought to address some of the most challenging problems with developmental and college-level math: course content and teaching methods. Multiple math pathways, which diversify the math course pathways and content that students are required to take based on their intended careers, is one mechanism for addressing these issues. Rather than the "algebra-for-all" model that has been typical in most colleges, math pathways align math content with students' majors; students who concentrate in fields such as social sciences or nursing take statistics courses, for example, while humanities majors might take quantitative literacy courses. Additionally, many math pathways models also replace typical lecture-based teaching with instructional techniques that have been shown to be effective at increasing student engagement and learning.[6] These methods include activities such as contextualizing math learning within real-life situations or promoting active, student-centered learning models that make students active participants in problem solving.

This report presents the findings of a study of a popular math pathways innovation, the Dana Center Mathematics Pathways (DCMP, formerly the New Mathways Project). It examines the effects of the implementation of the DCMP's curricular models, which entail changes in both math content and instructional methods in developmental education and college-level courses while also accelerating developmental students' progress into college-level math.[7] This is one of

---

Maggie Thompson, *Remedial Education: The Cost of Catching Up* (Washington, DC: The Center for American Progress, 2016).

[5]Barnett et al. (2018); Shanna Smith Jaggars, Michelle Hodara, Sung-Woo Cho, and Di Xu, "Three Accelerated Developmental Education Programs: Features, Student Outcomes, and Implications," *Community College Review* 43, 1 (2014): 3-26; Angela Boatman, *Evaluating Institutional Efforts to Streamline Postsecondary Remediation: The Causal Effects of the Tennessee Developmental Course Redesign Initiative on Early Student Academic Success* (New York: National Center for Postsecondary Research, 2012); Alexandra W. Logue, Mari Watanabe-Rose, and Daniel Douglas, "Should Students Assessed as Needing Remedial Mathematics Take College-Level Quantitative Courses Instead? A Randomized Controlled Trial," *Educational Evaluation and Policy Analysis* 38, 3 (2016); Elizabeth Zachry Rutschow, Maria Scott Cormier, Dominique Dukes, and Diana E. Cruz Zamora, *The Changing Landscape of Developmental Education Practices: Findings from a National Survey and Interviews with Postsecondary Institutions* (New York: Center for the Analysis of Postsecondary Readiness, 2019).

[6]Michelle Hodara, *Reforming Mathematics Classroom Pedagogy: Evidence-Based Findings and Recommendations for the Developmental Math Classroom* (New York: Community College Research Center, Teachers College, Columbia University, 2011); Vilma Mesa, Sergio Celis, and Elaine Lande, "Teaching Approaches of Community College Mathematics Faculty: Do They Relate to Classroom Practices?" *American Educational Research Journal* 51, 1 (2014): 117-151; Thomas P. Carpenter, Megan Loef Franke, and Linda Levi, *Thinking Mathematically: Integrating Arithmetic and Algebra in Elementary School* (Portsmouth, NH: Heinemann, 2003).

[7]The DCMP curricular models are one version of the DCMP that colleges can choose to implement. Colleges may also choose to implement a broader version of the DCMP model that does not use the DCMP curricula. As Chapter 2 discusses, this broader model is based on the Dana Center's four principles for the DCMP and allows colleges more flexibility in structuring course sequences and revising course content and instruction.

three primary studies by the Center for the Analysis of Postsecondary Readiness (CAPR), a joint venture of MDRC and the Community College Research Center at Teachers College, Columbia University, and supported by the U.S. Department of Education's Institute for Education Sciences. Using a randomized controlled trial, this evaluation examines how four Texas community colleges implemented the DCMP at their institutions in developmental and college-level classrooms and looks at the differences in instruction between these courses and colleges' standard math courses. Additionally, the study analyzes the impact of the DCMP on students' academic outcomes for up to four semesters and compares the costs of the initiative with colleges' standard course pathways.

Overall, the study reveals that colleges remained faithful to the DCMP curricular models, making major changes to intra- and cross-institutional policies that supported the DCMP's implementation at a larger scale. Students in DCMP courses had strikingly different instructional experiences from the experiences of students in standard courses. While lecture and individualized work dominated standard classes, over two-thirds of the DCMP students noted that they worked regularly with other students to solve math problems contextualized in real-life situations. After three semesters, the researchers saw strong and statistically significant impacts on DCMP students' completion of developmental and college-level math courses.[8] The DCMP did not affect students' persistence in college; overall credit accumulation; or successful completion of a degree, certificate, or transfer to a four-year institution after three semesters, though those effects are unlikely to emerge in so short a period. After initial start-up costs for the DCMP program, colleges were able to implement it at relatively low cost. Ongoing costs were, on average, $19,340 per year, less than 1 percent of the colleges' overall annual operating revenue.

Why Implement Math Pathways?

The preponderance of evidence shows that there is a disconnect between the demands of the 21st century economy and the math education that postsecondary schools typically offer their students. Although postsecondary schools traditionally require college-level algebra for graduation, only 22 percent of workers are able to use math that is more complicated than decimals, fractions, and percentages.[9] Many more require basic middle school math and quantitative literacy skills, such as interpreting graphs and charts, or being able to answer math problems that occur in everyday life.[10] Moreover, studies have shown that traditional developmental math courses rely on outdated instructional methods, such as rote memorization of math formulas

[8]Statistical significance measures the likelihood that a relationship exists between two variables that is not the result of chance.

[9]Michael J. Handel, "What Do People Do At Work? A Profile of U.S. Jobs from the Survey of Workplace Skills, Technology, and Management Practices (STAMP)," *Journal for Labour Market Research* 49 (2016): 177-197.

[10]John P. Smith, "Tracking the Mathematics of Automobile Production: Are Schools Failing to Prepare Students for Work?" *American Educational Research Journal* 36, 4 (1999): 835-878; Celia Hoyles, Celia, Richard Noss, and Stefano Pozzi, "Proportional Reasoning in Nursing Practice," *Journal for Research in Mathematics Education* 31, 1 (2001): 4-27.

and routine practice, rather than the active learning, concept-based models that are the norm in nations with high math achievement.[11]

The implementation of multiple math pathways models has become a popular mechanism for responding to these challenges. Rather than requiring students to take algebra courses that will not be relevant to their future work, math pathways allow students to take math courses that are more aligned with their future careers. These pathways are often built around three core math subjects: quantitative literacy for humanities majors; statistics for social and health sciences majors; and a calculus pathway for students majoring in science, technology, engineering, or mathematics (STEM). Many models also begin with an accelerated and revised developmental course, and prominent models such as Carnegie Math Pathways' Statway/Quantway and the DCMP have provided curricula that promote more student-centered instruction in which students work together and take an active role in problem solving and sharing strategies.[12] More than 30 percent of public two-year and four-year colleges report having implemented these pathways on a nationally representative survey in 2016. Quasi-experimental studies and randomized controlled trials have begun to show the promise of these pathways models in increasing developmental students' completion of college-level math and accumulation of credits.[13] However, despite the increasing popularity of math pathways models, very few rigorous studies have examined their effects on students' outcomes, and none has examined how differing instructional environments may affect students' learning experiences and attitudes toward math.

The DCMP in Texas

The Charles A. Dana Center at the University of Texas at Austin launched the DCMP in 2011 and, with the support of the Texas Association of Community Colleges, garnered the agreement of all 50 Texas community colleges to implement the DCMP at their institutions. Based around four key principles, the DCMP aims to help colleges implement math pathways aligned with students' programs of study in both developmental and college-level courses, develop strategies to support students as learners, and integrate evidence-based curricular and pedagogical strategies in these courses.[14] The Dana Center is now heavily involved in promoting the implementation of

[11]Stigler and Hiebert (1999); Hiebert (2003); Givvin, Stigler and Thompson (2011); Stigler, Givvin, and Thompson (2010); Lindsey E. Richland, James W. Stigler, and Keith J. Holyoak, "Teaching the Conceptual Structure of Mathematics," *Educational Psychologist* 47, 3 (2012): 189-203; Grubb (2013).

[12]https://carnegiemathpathways.org; Pamela Burdman, Kathy Booth, Chris Thorn, Peter Riley Bahr, Jon McNaughtan, and Grant Jackson, *Multiple Paths Forward: Diversifying Mathematics as a Strategy for College Success* (San Francisco: WestEd and Just Equations, 2018); Dana Center Mathematics Pathways, *DCMP Curriculum Design Standards* (Austin, TX: Dana Center Mathematics Pathways, 2017).

[13]Logue, Watanabe-Rose, and Douglas (2016); Jon Norman, *Pathways Post-Participation Outcomes: Preliminary Findings* (Stanford: Carnegie Foundation for the Advancement of Teaching, 2017).

[14]For more information, see https://dcmathwathways.org/dcmp.

the DCMP nationwide and works with more than 15 states to help them implement multiple math pathways.[15]

The Dana Center also created curricula that colleges could use to support the implementation of the developmental and college-level math courses in three pathways (statistics, quantitative literacy, and a path to calculus) at their colleges. (See Figure ES.1.) These curricular models begin with a condensed developmental math course that is targeted to students assessed as needing one to two developmental courses,[16] followed by an introductory college-level math class for each math pathway, respectively. The curricula for DCMP developmental and college-level math courses apply active learning and contextualized math instructional models that emphasize collaborative student learning and require students to demonstrate their ability to read, write, and communicate orally about their math learning. (See Table ES.1.) This study is focused on the implementation and effects of this curricular model.

CAPR's Evaluation of the DCMP

CAPR's evaluation of the DCMP consists of three primary components: (1) an investigation of colleges' institutional implementation of the DCMP curricular pathways, their fidelity to the DCMP curricular models, and the contrast between the DCMP courses and colleges' standard developmental and gateway college-level courses;[17] (2) an impact study investigating the effects of the DCMP on students' academic outcomes; and (3) a cost study. CAPR researchers conducted the study at four colleges in Texas (El Paso Community College, Trinity Valley Community College, and two colleges from the Dallas County Community College District — Brookhaven College and Eastfield College). The key outcomes tracked in the study include completion of the developmental math sequence, completion of a college-level math course, math credits earned, total credits earned, and receipt of a degree or transfer to a four-year college.

Advisors identified students who were interested in and eligible for participating in the DCMP based on their need for developmental math and intended major. They randomly assigned students to either the program group or the standard group. Program group students had the opportunity to enroll in the DCMP, which consists of a one-semester accelerated developmental math course followed by a college-level statistics or quantitative reasoning course in the second

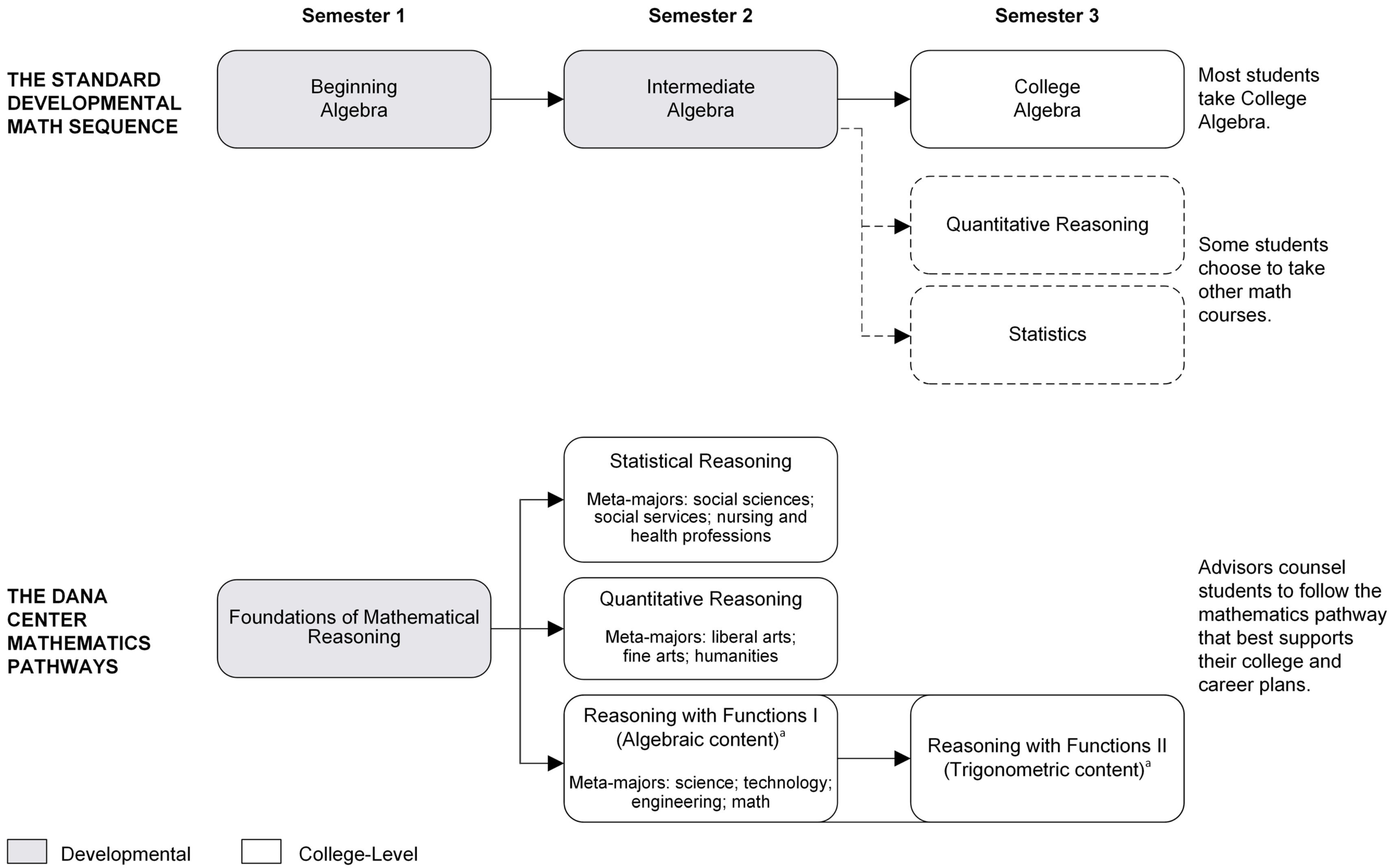
[15]California, Georgia, Maine, Maryland, New Mexico, Colorado, Indiana, Missouri, Montana, Nevada, Ohio, Arkansas, Massachusetts, Michigan, Oklahoma, Washington and North Carolina (https://dcmathpathways.org/where-we-work).

[16]During the period of this study, the assessment of students' college readiness is based on a Texas-wide placement test for entering students called the Texas Success Initiative Assessment (TSIA) or their ACT or SAT scores. The Texas Higher Education Coordinating Board sets the cutoff score at which students are deemed college-ready or in need of developmental courses, and a range of scores that qualify students for developmental courses, below which students must seek alternative services. Colleges have the discretion to set their own cutoff scores within this range to determine students' level of developmental need and the number of developmental courses they must take.

[17]A gateway course is the first college-level course that a student takes.

Figure ES.1

A Comparison of Mathematics Courses for Students with Two Levels of Developmental Need



NOTE: [a]Evaluation of Reasoning with Functions I and II is outside of the scope of this study.

Table ES.1

Key Distinctions Between Standard Math Courses and DCMP Courses

Program Component	Standard Math Courses	DCMP Courses
Course Structure		
Course sequence	The number of courses required depends on the student's level of developmental need.	Students with one or two levels of developmental need take only one developmental course.
Math content	Developmental courses emphasize algebraic skills and are designed to lead to college-level algebra.	The developmental course emphasizes quantitative literacy, statistics, and algebraic reasoning skills. College-level courses are diversified based on major.
Instruction and curricular materials		
Curricular materials	Varies; traditionally, the curricula focus on discrete skills and topics.	Curricula are organized around broad mathematical concepts and big ideas.
Pedagogical approach	Varies; traditionally, classes are lecture-based.	Instruction employs a variety of approaches including small-group work, class discussions, and interactive lectures. Students are actively involved in analyzing data and problem-solving.
Constructive perseverance	Varies; this is not a focus in standard math instruction.	Students develop metacognitive skills such as the ability to work through challenging tasks and self-monitor learning.
Problem solving	Varies; traditionally, students learn formula-based applications and rote practice using one solution method.	Instruction supports applying previously learned skills to unfamiliar and nonroutine problems; students develop multiple strategies and solution methods.
Context and interdisciplinary connections	Varies; generally, the use of formulas, equations, and symbols are taught as discreet skills.	Math problems are contextualized around real-life situations and/or integrate academic disciplines; curricula use real data sets and incorporate realistic applications.
Reading and writing	Varies; there are traditionally some word problems. Class is focused on equations and rote practice in applying formulas.	Students develop the ability to read about math and explain solutions in writing.
Use of technology	Varies; instruction is traditionally textbook-based. There is limited use of calculators.	Students regularly use calculators and computers in class and at home

SOURCE: Dana Center Mathematics Pathways (2017).

semester.[18] The standard group had the opportunity to enroll in the colleges' standard algebra-focused developmental course offerings, and once college-ready, could enroll in any college-level math course. Students entered the study from fall 2015 through spring 2017 for a total sample of 1,411 students across the four colleges.

CAPR researchers made field visits to each of the colleges to assess the implementation of the DCMP courses and their contrast with standard math courses, which included interviews with faculty, staff, and administrators; observations of DCMP and non-DCMP classes; and student focus groups. They distributed surveys to students when they entered the study and again near the end of their first semester in the study.[19] CAPR researchers also collected college course placement and transcript data to ascertain students' level of developmental need and academic outcomes. Finally, they collected cost data from college administrators involved with the program to analyze the startup and ongoing costs of the DCMP relative to colleges' standard courses. This report provides findings on students' outcomes over three semesters for the entire sample and four semesters of findings for the first three cohorts.

Findings

Key findings from the study include:

- **Colleges were able to revise many institutional policies that enabled them to implement the DCMP and offer DCMP courses to many more students than was possible before the study began, though challenges remained with targeting all eligible students.**

The four colleges that participated in the study were successful in implementing a number of complex institutional changes to support the expansion of the DCMP. These changes included revising math requirements for majors that would be better aligned with statistics and quantitative reasoning courses, changing advising practices so that they could more readily identify students' majors and place them in the appropriate math sequences, and ensuring that faculty and staff members had the training and supports they needed to understand the DCMP model and implement the revised curricula and instructional approaches. As a result of these revisions, each of the colleges offered three sections or more during most of the semesters of the study. Three of the colleges had started with only one or no DCMP developmental course section.

However, while colleges were able to enroll more students in the study, none of the colleges targeted and brought in all the students who were likely eligible for the study, often because

[18]Though the colleges participating in the study also implemented college-level statistics and quantitative reasoning courses using DCMP curricula, they generally only offered one or two sections of these courses, making it difficult for students in the program group to enroll. Therefore, successful DCMP students were offered the opportunity to enroll in the colleges' standard statistics and quantitative reasoning courses as well as those that used the DCMP curricula.

[19]The first cohort (fall 2015) of students received the survey toward the end of their second semester of the study (spring 2016). Unlike the other cohorts, these students were asked questions regarding their math class in the previous semester.

of the extra advising time needed to place students in the correct pathway or the lack of clarity about alignment of policies and math requirements with four-year colleges.

- **Although colleges were successful at revising most intra-institutional practices, it remained challenging to align policies with those of four-year colleges.**

The colleges in the study were able to successfully negotiate with many four-year colleges to ensure that students' math courses would be accepted upon transfer, which may have been in part a result of the written agreements that CAPR researchers and the Dana Center helped broker with these colleges. However, while colleges made good progress with these efforts, negotiations sometimes remained challenging because some four-year colleges wanted to require specific types of math courses for particular majors (such as Statistics for Psychology for psychology majors). As a result, some advisors had concerns about placing students in the program, which led to difficulties with student recruitment in the first two semesters. For instance, some advisors were hesitant to put nursing students, a high enrollment major, into math pathways courses because some four-year colleges continued to require college-level algebra courses for this major.

- **Virtually all the developmental and college-level DCMP courses remained faithful to the DCMP's revised curricula and pedagogy, although the implementation of active learning, constructive perseverance,[20] and reading and writing was less consistent in some small classes and in some classes with English language learners.**

Classroom observations, instructor interviews, and student focus groups revealed that the schools implemented virtually all DCMP courses with relatively strong fidelity to the model. Students in most classes worked collaboratively to solve multistep word problems, using a method or an answer derived in an initial question to solve additional and more complicated queries. Students were also observed sharing strategies and demonstrating their understanding of math concepts orally or in writing. In focus groups, students regularly commented on the course's distinct pedagogy, and instructors generally reported following the revised instructional practices recommended by the DCMP curricula. In responses to the survey students received near the end of their first semester in the study, an overwhelming majority of program group students reported working with other students in small groups, solving real-life problems, reading, writing out their reasoning, and orally sharing their work using math terminology.

- **Instruction in DCMP courses contrasted strongly with colleges' standard developmental course offerings and college-level algebra courses.**

In contrast to DCMP classes, instruction in the colleges' standard developmental and algebra classes typically centered on lecture and individual student work. Students rarely interacted with one another, although they interacted with the teacher in response to a question posed to the

[20]Constructive perseverance is a student's ability to work through challenging problems.

class. On the student survey, less than 30 percent of students in the standard group reported regularly working with other students on problems, working in small groups, explaining their work orally, or writing out their reasoning. Less than 40 percent reported regularly reading in class or learning math in the context of real-life situations.

- **After three semesters, the DCMP had a positive impact on students' completion of the developmental math sequence and their likelihood of taking and passing college-level math, and the number of math credits they earned. The study found no impacts on overall credit accumulation or on a preliminary measure of successful college completion, none of which is likely to occur in this short timeframe.**

Students participating in the DCMP were 8 percentage points more likely to pass a developmental math course and almost 24 percentage points more likely to complete the developmental math sequence and become college-ready during their first three semesters after entering the study compared with their standard group peers. Program group students were also 11 percentage points more likely to pass a college-level math course during their second semester, and 7 percentage points more likely to have ever passed a college-level math class by the end of their third semester. DCMP students also, on average, earned 0.2 more college-level math credit than the standard group, and both groups had similar overall credit accumulation during the first three semesters. While preliminary findings show a small impact of the DCMP on earning a certificate by the end of two years of college, the study found no impact on the combined measure of earning a degree or transferring to a four-year college during the three-to-four-semester follow-up period.

- **Exploratory analyses suggest that the impacts of the DCMP were greater for part-time students and students assessed as needing multiple developmental courses.**

Exploratory analyses of different subgroups in the sample suggest that the impacts of the DCMP may have been concentrated in the group of students who were lower performing on the math placement exam before entering college (those who were assessed as needing two or three developmental courses, representing 84 percent of the study sample). The program also appears to be somewhat more effective for part-time students (who tend to struggle more with academic performance and credit accumulation and are more likely to drop out) compared with full-time students. In general, analyses suggest that students performed equally well in the DCMP program group regardless of their race, ethnicity, or gender.

- **Both start-up costs and net ongoing direct costs to the college from the DCMP in this study are fairly low, though the colleges also received many supports from the Dana Center that are not included in these estimates.**

The average institutional start-up cost, or costs associated with initially implementing the DCMP, was about $140,450 per college over two years. Most of the start-up costs were for administration and included any administrative support, which ranged from working to align the courses, planning which courses would be offered, providing clerical support for the DCMP, and conducting communications and leadership meetings about the DCMP. The ongoing net cost of the DCMP, or the cost to the colleges after initial implementation for activities beyond what is needed for standard developmental math, for one school year was $19,340 per school on average. The main ongoing net cost was for faculty member training and stipends. Both start-up costs and net ongoing direct costs on an annual basis are less than 1 percent of the colleges' annual operating revenue.

However, colleges did receive many additional supports from the Dana Center for implementing the DCMP, such as faculty member training, assistance in negotiating policies with four-year colleges, and site visits from Dana Center leaders, which the colleges received free of charge. The estimated start-up costs to the Dana Center for these services was $295,057.

Implications of the Study Findings

Key implications are:

- **The DCMP is effective in helping students succeed in college math. It is too soon to assess the DCMP's effect on students' longer-term academic outcomes.**

Students in the program group significantly increased their completion of developmental and college-level math, and early impacts suggest that the DCMP may have been effective in helping students' reach the longer-term outcome: receipt of a certificate. However, it is too soon to tell whether the DCMP affects students' persistence, overall credit accumulation, and receipt of an associate's degree. A longer timeframe for analyzing these outcomes will be particularly important, given that many students in the study were enrolled part time.

- **Pairing the DCMP with other interventions may bolster students' achievement.**

The DCMP could be connected with other developmental reforms that have shown promise for improving students' success, and in fact such connections are already under way. For instance, in 2017, the state of Texas legislated that postsecondary institutions offer developmental courses as corequisites to college-level courses, meaning that students receive developmental supports while enrolled in college-level math. The Dana Center has developed curricula and supports to aid colleges in implementing these mandates with the DCMP. A rigorous study of a corequisite math pathways model at the City University of New York (CUNY) has revealed the strong impacts that corequisite math pathways can have on developmental students' completion of a college-level math class.[21]

Pairing the DCMP with more comprehensive reforms may also be promising. These reforms include programs such as CUNY's Accelerated Study in Associate Programs (ASAP), which provides multiple financial and social supports to students throughout their college career,

[21]Logue, Watanabe-Rose, and Douglas (2016).

or guided pathways, which provides students with more structured guidance and supports for career and course pathways in an effort to help them complete college as efficiently as possible.[22] Rigorous studies of ASAP reveal large effects on helping students reach difficult-to-achieve measures such as graduation. Additionally, because these types of comprehensive reforms focus less often than the DCMP on changes to course content and instruction, the DCMP may provide complementary supports to students' success within these larger initiatives.

- **It is possible to improve students' experiences with math.**

Many postsecondary reforms have shied away from attempts to change classroom instruction. Some of this may stem from a desire to preserve faculty members' autonomy — as well as from research showing that it is extremely difficult to change faculty members' teaching methods.[23] Despite these impediments, the Dana Center was able to develop a curricular model that the colleges under study implemented successfully, dramatically changing students' experiences with learning math. While teachers encountered challenges implementing some parts of the curricula, by and large, most were able to provide a qualitatively different instructional experience for students. Surprisingly, they accomplished these changes with relatively limited training. Nearly all instructors participated in a multiday training event on the DCMP curricula with Dana Center staff, and many also voluntarily participated in online forums and mentoring that supported the implementation. Many instructors also reported that preparing to teach these classes was time-intensive in their initial semester because they required using new instructional approaches. However, most were able to successfully make these changes even in their first semester of teaching this curriculum.

- **The striking contrast in instruction between the DCMP and the colleges' standard courses suggests that college leaders and reformers should pay much more attention to math teaching methods in higher education.**

DCMP courses tended to actively engage students, in terms of their class activity as well as the nature of the material. In contrast, observations and interviews with instructors of standard developmental and college-level algebra classes presented a sobering view of the integration of these practices college-wide. Very few students in these traditional courses interacted with one another or reported understanding how they would use the math they were learning in their everyday lives. Classes tended to be silent except for the teacher's lecturing and requests for solutions to problems. Such findings reveal that instruction in many postsecondary math classes has a long way to go toward adopting the types of student-centered, contextualized learning practices that math experts recommend.[24]

---

[22]Davis Jenkins, Hana Lahr, and John Fink, *Implementing Guided Pathways: Early Insights From the AACC Pathways Colleges* (New York: Community College Research Center, 2017).

[23]Janet Quint, *Professional Development for Teachers: What Two Rigorous Studies Tell Us* (New York: MDRC, 2011).

[24]National Research Council, *Eager to Learn: Educating Our Preschoolers,* Committee on Early Childhood Pedagogy: Barbara T. Bowman, M. Suzanne Donovan, and M. Susan Burns, eds. (Washington,

- **Postsecondary education policymakers need to integrate student-centered, contextualized instructional models such as the DCMP throughout their math programs to improve students' confidence, engagement, and enjoyment of math.**

Even among the students in this study, far too many continue to struggle with math. After three semesters, more than 40 percent of program group students and more than 65 percent of standard group students had not completed their developmental math requirements after three semesters, and only 25 percent of DCMP students had successfully completed a college-level math course. Additionally, while many students in the DCMP developmental course indicated that their math class had increased their enjoyment of and confidence in math, the majority did not report feeling more confident in math or enjoying math learning. This finding suggests that while a class can improve some students' perspectives of math, there is a need for much more fundamental reforms aimed at building their enjoyment and confidence with math over time.

As such, mathematicians, instructors, and policymakers might consider seeking to develop more engaging math content and instructional approaches that can help build students' interest in math over time. Such initiatives such as Building Educated Leaders for Life (BELL) and the Success for All Middle School Mathematics Program have focused on developing more effective math instructional models in kindergarten through grade 12.[25] Postsecondary leaders could turn to centers such as Patrick Henry Community College's SCALE Institute, Project Kaleidoscope, or the Dana Center's FOCI model, which works with instructors in person and remotely to help them integrate active learning and other promising instructional techniques into math courses.[26]

- **Educators need to develop stronger measures of math teaching and learning to better understand how to improve students' long-term outcomes.**

This study is one of a few that has attempted to assess how an intervention to change instruction in developmental classes and how students' experiences in the classroom may affect their understanding, engagement, and enjoyment of math. However, more accurate and uniformly applied measures of instruction and student learning might provide more comprehensive answers to the question of how to improve math learning. Specifically, very few instruments exist to measure whether and how courses achieve their stated objectives. Additionally, educators need new mechanisms for assessing students' acquisition and application of math skills in real-life settings

DC: National Academy Press, 2001); National Council of Teachers of Mathematics, *Principles and Standards for School Mathematics* (Reston, VA: National Council of Teachers of Mathematics, 2000); Committee on the Undergraduate Program in Mathematics of the Mathematical Association of America, *Undergraduate Programs and Courses in the Mathematical Sciences: CUPM Curriculum Guide 2004* (Washington, DC: The Mathematical Association of America, 2004).

[25]MDRC, *Math Matters* (New York: MDRC, 2015).

[26]For more information on SCALE, visit the website of the Southern Center for Active Learning Excellence http://scaleinstitute.com/; for more information on FOCI, visit the Focused Online Collaborative Interactions website https://www.utdanacenter.org/our-work/higher-education/higher-education-services/foci; and for more information on Project Kaleidoscope, visit the Association of American Colleges and Universities website, https://www.aacu.org/pkal.

to better understand whether and how what the students take away is aligned with their lives and careers. The development of these new measures, and the research findings that come from them, represent the next frontier for improving the field's understanding of how to improve students' math learning and engagement.

Conclusion

Recent research on developmental education reform has shown that many structural and sequencing reforms, such as allowing students to take developmental education and college-level courses simultaneously or compressing two-semester developmental courses into one semester, hold promise for improving developmental students' outcomes.[27] However, most of these studies have focused on helping students get through math. Far fewer have focused on effective ways to attract students to math and math-focused careers.

Building an interest and engagement in math is critical to the future of the U.S. economy and students' ability to earn living-wage jobs as the labor market demands candidates with strong logic and critical thinking skills as well as the ability to interpret the myriad charts, graphs, and statistics integral to many jobs. As international studies have revealed, most American adults are currently unable to demonstrate these skills effectively, which makes their ability to secure and keep these jobs much more difficult. This research reveals the critical need to find ways to improve people's understanding of math and how it applies to their everyday life and work. And it finds that the method at the heart of the DCMP curricular models — and the instructional methods national experts recommend — can positively change students' math abilities and perspectives in two semesters. These findings raise the prospects for solutions to Americans' innumeracy epidemic, if educators integrate this type of instruction in many more math courses across the country.

[27]For examples, see Logue, Watanabe-Rose, and Douglas (2016); Boatman (2012); Jaggars, Hodara, Cho, and Xu (2014).

Chapter 1

Introduction

Analyses of literacy and numeracy levels worldwide by the Organisation for Economic Cooperation and Development (OECD) suggest that the U.S. population has one of the lowest numeracy levels among developed nations. Sixty-four percent of American adults are unable to use and interpret math problems that most higher-level jobs require, and a full 30 percent can only perform basic mathematical computations such as arithmetic or solve simple one-step operations such as counting.[1] Such challenges reveal the critical need to improve American adults' math skills.

Nonetheless, many people continue to struggle with learning math, including in college preparatory math classes, also known as developmental, or remedial, math. The challenges of developmental education — and developmental math, in particular — have become well known. Large proportions of students, up to 70 percent in two-year colleges and 40 percent in four-year colleges, enter college taking developmental classes — and most are required to take at least one developmental math class.[2] Research has revealed that few of these students are successful in these courses: 40 to 50 percent fail to complete all their developmental math requirements.[3] The cost of developmental courses is steep: They can cost students and their families upward of $1 billion a year nationally.[4] Far too often, these students leave colleges and universities with debt and no degree or credential to show for it.[5]

These issues have led higher education leaders to search for ways to increase students' success in developmental courses, which has led to rapid change in the field. Reforms have been made to developmental education assessment and placement as well as to the courses students take.[6] Much of the effort has focused on reducing or eliminating students' time in developmental education by compressing developmental course sequences into shorter periods ("compressed courses"), allowing students with developmental needs direct entry into college-level courses with supports ("corequisite courses"), and revising math course content and instruction so that they provide student-centered learning approaches aligned with students' careers (known as "multiple math pathways"). State policy has been a driver in this process, with

[1]Organisation for Economic Cooperation and Development (n.d.); and Program for the International Assessment of Adult Competencies, and U.S. Department of Education, National Center for Education Statistics (n.d.).

[2]Chen (2016); Bailey, Jeong, and Cho (2010).

[3]Bailey, Jeong, and Cho (2010); Chen (2016). Chen's study only looked at students who enrolled in courses rather than students referred to these courses, while Bailey, Jeong, and Cho analyzed developmental education referrals.

[4]Barnett et al. (2018).

[5]U.S. Department of Education (2015).

[6]Barnett et al. (2018); Zachry Rutschow (2019).

at least 21 states now mandating or recommending changes to developmental education for their member institutions.[7]

Rigorous studies have also been confirming the promise of these reforms. For instance, quasi-experimental and randomized controlled trial studies of multiple measures assessment processes for identifying students' college readiness (such as including high school performance measures along with standardized tests in course placement decisions), corequisite courses, and multiple math pathways have shown that the reforms can improve students' progress to and completion of college-level courses.[8] However, many of these studies have focused on revisions to the structure or sequencing of developmental and college-level math courses, with far fewer examining how changes to instruction might affect students' success. To date, studies of classroom-based interventions, such as the revision of course content in math pathways reforms, have shown that changing content has promise. However, they have not included a direct analysis of how pedagogical revisions may contribute to students' success.[9]

This report provides an analysis of a popular math pathways innovation, the Dana Center Mathematics Pathways (DCMP), which incorporates changes to content and instruction as well as strategies for accelerating students' progress through developmental math. The study of DCMP that is the basis for the analysis employs a randomized controlled trial, in which students are randomly assigned to a program group that is eligible to receive DCMP courses and to a standard group that receives the college's typical developmental and college-level math course sequence. Researchers then test to see if statistically significant differences — differences that do not arise by chance — exist in the outcomes of the two groups. Because the program and standard groups are similar at the time of entry into the study, a randomized controlled trial ensures that differences in motivation and demographic characteristics do not bias the study results. Therefore, researchers can attribute any differences in the program and standard groups' outcomes to the DCMP's impact with a high level of confidence.

This evaluation is one of three primary studies in the Center for the Analysis of Postsecondary Readiness (CAPR), supported by the U.S. Department of Education's Institute of Education Sciences and jointly led by MDRC, a nonprofit, nonpartisan education and social policy research organization, and the Community College Research Center at Teachers College, Columbia University. This study investigates how four Texas community colleges (El Paso Community College; Trinity Valley Community College; and Brookhaven College and Eastfield College, both in the Dallas County Community College District) implemented the DCMP at their institutions and in developmental and college-level classrooms and examines the differences in instruction between these courses and colleges' standard math courses. Additionally, the study examines the impact of the DCMP based on five confirmatory outcomes,[10] including students' completion

[7]Whinnery and Pompelia (2018).

[8]Barnett et al. (2018); Jaggars, Hodara, Cho, and Xu (2014); Boatman (2012); Logue, Watanabe-Rose, and Douglas (2016).

[9]Logue, Watanabe-Rose, and Douglas (2016); Strother, Campen, and Grunow (2013).

[10]Confirmatory outcomes are the primary outcomes prespecified by the research team that are directly connected to the hypotheses being tested and that are used to determine whether the intervention had an impact.

of the developmental math sequence, completion of a college-level math course, math credits earned, total credits earned, and receipt of a degree or certificate or transfer to a four-year college. The evaluation also considers the costs of the initiative compared with colleges' standard courses. Key findings from this study are:

- Colleges made important strides in revising institution-level policies to support the implementation of the DCMP, though some challenges remained, such as alignment with four-year colleges.
- The contextualized and more student-centered DCMP curricula were implemented with relatively strong fidelity to the DCMP model, and qualitatively changed the ways in which students experienced and learned math in developmental courses. Students in the DCMP courses noted that they were actively problem-solving in small groups with other students much more often and had a better understanding of how they would use math in their everyday lives than students in the standard group.
- Program group students completed developmental and college-level math courses at a higher rate than students in the standard group. Exploratory analyses suggest that the impacts of the DCMP were greater for part-time students and students assessed as needing multiple developmental courses.
- The DCMP had a positive impact on students' completion of developmental math, their likelihood of taking and passing college-level math, and their earning of college-level math credits within the first three college semesters. At the time of the analysis, it did not affect students' persistence, overall credit accumulation, or receipt of an associate's degree or transfer in the overall sample, although the research revealed small impacts among the first three cohorts on receipt of a certificate.
- Both start-up costs and net ongoing direct costs to the college from the DCMP are fairly low. The average start-up cost per college over two years was about $140,450. The ongoing net cost of the DCMP for one school year on average was $19,340 per school. Both costs on an annual basis are less than 1 percent of the colleges' annual operating revenue.

Why Revise Math Course Content and Instruction?

While many developmental math reforms have focused on changing the sequence and structure of these courses, research suggests that the content and instruction in both developmental and college-level math courses also need revision.[11] For instance, many colleges require that students complete a college-level algebra course to receive their degree despite the fact that only 22 percent

[11]Grubb (1999); Hern (2013); Edgecombe and Bickerstaff (2018).

of workers use math more complicated than decimals, fractions, and percentages.[12] Instead, many career fields require basic middle school math and quantitative literacy skills, such as the ability to read statistical charts and graphs or work with fractions.[13] Studies have also shown that developmental courses often focus on rote memorization of math formulas and routine practice rather than the active learning and concept-based learning models used by nations with high math achievement.[14]

Given these challenges, many college leaders have begun calling for and implementing developmental and college-level math courses with revised content and pedagogy. With many careers demanding strong statistical and quantitative literacy skills, math leaders throughout the country have advocated for more college math courses that emphasize these skills.[15] Additionally, experts have argued for more pedagogical reforms that emphasize students' conceptual understanding of math and application of this knowledge within the context of practical situations that allow students to see how math is connected to their everyday lives.[16] More student-centered, active-learning approaches, in which students play a key role in actively problem-solving with other students, are also seen as important to promoting math understanding.[17] Finally, some studies have shown that developmental (and college-level) students have more confidence in their math and learning abilities than math instructors may give them credit for, suggesting that faculty may be able to further advance these characteristics in their instruction.[18]

A Strategy to Improve Math Instruction and Success

The implementation of multiple math pathways, which diversifies the math courses students take based on their intended careers, has become a popular mechanism for revising math course content and pedagogy. Multiple math pathways are often organized around three core math subjects: quantitative literacy for humanities and liberal arts majors; statistics for social and health sciences majors; and a calculus pathway for students majoring in science, technology, engineering, or mathematics (STEM). Often, math pathways models recommend beginning reforms by revising content at the developmental level, giving students an opportunity to take developmental courses that integrate more statistics and quantitative literacy content.[19] Additionally, some math pathways models, such as the Carnegie Math Pathways' Statway and Quantway and the DCMP, also

[12]Handel (2016).

[13]Smith (1999); Hoyles, Noss, and Pozzi (2001).

[14]Stigler and Hiebert (1999); Hiebert (2003); Givvin, Stigler, and Thompson (2011); Stigler, Givvin, and Thompson (2010); Richland, Stigler, and Holyoak (2012); Grubb (2013).

[15]Liston and Getz (2019); Strother, Van Campen, and Grunow (2013); American Mathematical Association of Two-Year Colleges (2018); Saxe and Braddy (2015).

[16]Hiebert and Grouws (2007); Richland, Stigler, and Holyoak (2012); Mesa, Celis, and Lande (2014); Carpenter, Frank, and Levy (2003).

[17]American Mathematical Association of Two-Year Colleges (2018); Saxe and Braddy (2015); Hodara (2011).

[18]Mesa (2012).

[19]https://carnegiemathpathways.org; Burdman et al. (2018); Dana Center Math Pathways (n.d. [b]).

integrate pedagogical reforms contextualizing math instruction into real-life situations and providing more small-group active-learning instructional models. Finally, several models have integrated these reforms into an accelerated developmental math course, allowing developmental math students to complete a college-level math course in one year.[20]

Many states are now recommending or mandating multiple math pathways and developing the infrastructure to support their implementation across their public two-year and four-year colleges.[21] Colleges appear to be heeding these calls. In CAPR's nationally representative survey of open-access two-year and four-year institutions, 41 percent of public two-year colleges and 32 percent of public four-year colleges offered math pathways courses.[22] A number of prominent college completion advocacy organizations also now promote the implementation of multiple math pathways as a key strategy for improving students' success.[23]

How Effective Are Multiple Math Pathways Models?

Research on multiple math pathways models is relatively limited; however, the few studies that exist demonstrate their promise for improving students' outcomes. Descriptive studies have been undertaken with Carnegie's Statway and Quantway, the DCMP, and the California Acceleration Project's models, each of which incorporates developmental acceleration techniques along with revised pedagogy and content in both developmental and college-level math. These studies showed promising increases in the number of students who complete both their developmental and college-level course requirements.[24] Descriptive studies of Statway and Quantway, in particular, reveal large increases in the number of students who complete a college-level course in one year — at rates double or triple those in traditional math courses and in less time.[25] Quasi-experimental studies using propensity score matching[26] also suggest that math pathways can have large effects on the number of students completing a college-level math course and their accumulation of credits.[27]

Additionally, a recent randomized controlled trial of a math pathways experiment at the City University of New York found promising results with math pathways that provided corequisite supports, or enrolled students directly in college-level classes with supports, to students in need of developmental math. These students were randomly assigned to one of three pathways:

---

[20]Logue, Watanabe-Rose, and Douglas (2016); Zachry Rutschow and Diamond (2015); Carnegie Math Pathways (n.d.).

[21]Bickerstaff, Chavarín, and Raufman (2018); Dana Center Mathematics Pathways (n.d. [d]).

[22]Zachry Rutschow et al. (2019).

[23]Complete College America (n.d.); Achieving the Dream (2018); AACC Pathways Project (n.d.).

[24]Hayward and Willett (2014); Yamada and Bryk (2016); Yamada, Bohannon, and Grunow (2016).

[25]Strother, Van Campen, and Grunow (2013).

[26]Propensity score matching (PSM) is a statistical method that seeks to reduce bias when comparing similar groups of people who did and did not receive an intervention.

[27]Zachry Rutschow, Diamond, and Serna-Wallendar (2017); Yamada and Bryk (2016); Yamada, Bohannon, and Grunow (2016).

the traditional developmental course sequence, the traditional developmental course with a weekly workshop that provided academic supports, or a college-level statistics class with a weekly workshop. This study found that 56 percent of students placed directly into the statistics courses with a corequisite support course completed a college-level math course, compared with 39 percent of students in the traditional developmental course sequence and 45 percent of students in the developmental courses with supports. Students in statistics classes also completed more college credits than students in the other two pathways and graduated at higher rates (8 percentage point difference) after three years of follow-up.[28]

These studies suggest that math pathways models hold strong promise for increasing students' success in math and in college. However, to date, no randomized controlled trial have analyzed how changes in course instruction, along with acceleration of the developmental sequence and revisions to course content, may affect students' outcomes. This evaluation of the DCMP seeks to bridge this gap by looking at the impact of these three components on students' outcomes.

The Evaluation of the DCMP

Launched in 2014 at four colleges in Texas, CAPR's randomized controlled trial evaluation of the DCMP consists of three primary research components: (1) an examination of the colleges' institutional implementation of the DCMP model, their fidelity to the DCMP curricular and instructional models, and the contrast between the DCMP and the colleges' standard developmental and gateway college-level courses; (2) an impact study investigating the effects of the DCMP on students' academic outcomes; and (3) a cost study. The key research questions are:

1. To what degree is there fidelity to the DCMP model across the colleges participating in the study? What aspects of the DCMP are consistent across colleges? What modifications did the colleges make and why?

2. How do the curricula and pedagogy in the DCMP courses differ from the colleges' standard developmental math courses?

3. Do DCMP students have better academic outcomes than students in standard developmental math courses, as reflected by students' completion of the developmental math sequence, their completion of a college-level math course, math credits earned, total credits earned, and students' receipt of a degree or certificate or transfer to a four-year college?

4. What are the costs to colleges to implement and maintain the DCMP?

[28]Logue, Watanabe-Rose, and Douglas (2016); Logue, Douglas, and Watanabe-Rose (2019).

Advisors at each of the four participating colleges identified students who were eligible for the study, including those who planned to major in social science or liberal arts (where statistics and quantitative reasoning skills are relevant) and those who tested as being in need of one or two developmental courses. The determination of the need for developmental courses was based on students' scores on the Texas Success Initiative Assessment, a placement test given upon entry into college, or their scores on the ACT or SAT.[29] Students whose scores were below the state-mandated cutoff were designated as being in need of developmental courses. Colleges generally used their own discretion to set score levels for different developmental course levels, within a range of scores set by the state.

Given the rush of new students before the semester begins, advisors generally identified students at new student orientations in the summer and late fall, although some students were also randomly assigned during the regular school semesters. Each of the participating colleges had many students who tested as being in need of developmental math and who were intending to pursue majors aligned with statistics and quantitative reasoning pathways. Nevertheless, advisors brought a relatively small proportion of these students into the sample in the first two semesters for several reasons: First, none of the schools had scaled the DCMP courses to reach large numbers of students. Second, advising for the DCMP often required more time, making it difficult for advisors to devote time to the process during busy periods. Third, some advisors had concerns about whether multiple math pathways courses would transfer to four-year colleges, leading them to continue directing students into algebra courses. These challenges, and their resolutions, are further explored in Chapters 2 and 3.

Advisors explained the study and the DCMP to students. Those who were eligible and interested were randomly assigned either to the program group, which had the opportunity to enroll in a DCMP sequence, starting with a revised and accelerated developmental math course followed by a college-level statistics or quantitative reasoning course; or to the standard group, which received the colleges' standard algebra-focused developmental and college-level math course sequences. Because assignment to the research groups is random, any differences in the outcomes of students in the program and standard groups can be attributed with a high level of confidence to the program itself, rather than to other differences such as prior math achievement or motivation.

Students in both the standard and program groups generally registered for courses immediately after random assignment. Advisors encouraged students to register for math classes for the upcoming semester, although not all students took advantage of this option. This may have been more the case for students who were in the standard group as students have often been known to delay their math requirements in favor of other courses.[30] Alternatively, they may have been reluctant to enroll in traditional math after being told about the DCMP.

---

[29]Texas Higher Education Coordinating Board (n.d.).

[30]Fike and Fike (2012).

Colleges in the Study

The four colleges that participated in the study represented both urban and rural communities, as well as small and large community colleges in the state of Texas. Brookhaven and Eastfield are separate, one-campus colleges located within the municipality of Dallas. Based on data from the Integrated Postsecondary Education Data System (IPEDS),[31] Brookhaven and Eastfield each enrolled more than 13,000 students per year as of 2017. El Paso Community College is the main community college in El Paso, consists of five campuses across the city, and enrolls nearly 30,000 students per year. Trinity Valley Community College is a rural community college that operates three campuses serving five counties in southeast Texas and enrolls just under 5,000 students per year. These colleges were chosen to participate in the study based on multiple factors, including the experience and strength of their DCMP implementation, the strength of the contrast between the DCMP and other math courses, their ability to scale the DCMP to enroll the targeted number of students, and the colleges' interest in participating in the study. As displayed in Table 1.1, these colleges are similar in the gender of their enrollees, with just over 40 percent of the

Table 1.1

College Student Body Characteristics

Characteristic	Brookhaven	Eastfield	El Paso	Trinity Valley
Total fall enrollment (N)	13,286	16,196	28,750	4,449
Full-time enrollment (%)	14.9	14.9	30.3	43.8
Men (%)	41.8	40.9	43.1	42.1
Race/ethnicity (%)				
White	24.2	20.7	7.4	58.8
Black	16.0	20.2	2.1	16.3
Hispanic	39.6	48.2	85.3	2.4
Other[a]	20.2	10.8	5.2	22.5
Enrolled within 12 months of high school graduation[b] (%)	57.2	66.4	74.0	68.7
College extent of urbanization[c]	Large suburb	Large suburb	Large city	Distant town

SOURCE: Data obtained from Integrated Postsecondary Data System (IPEDS). Final release values for fall 2017.

NOTES: Rounding may cause slight discrepancies in sums and differences.

[a]Researchers calculated race/ethnicity percentages from student totals. They combined races other than white, black, and Hispanic into "other" to more closely match baseline characteristics.

[b]"Enrollment within 12 months of high school graduation" is a percentage of all first-time degree-seeking undergraduate students enrolled at each college.

[c]"Degree of urbanization" categories come from IPEDS using Census Bureau methodology and are defined as follows: a "large suburb" is outside a principal city and inside an urbanized area with a population of 250,000 or more; a "large city" is inside an urbanized area and inside a principal city with a population of 250,000 or more; a "distant town" is inside an urban cluster that is between 10 and 35 miles from an urbanized area.

[31]IPEDS is a federal data base that collects aggregate data on student enrollment.

students reporting as male. Otherwise, the colleges are relatively different from one another. While a majority of students in all four participating colleges are recent high school graduates, El Paso Community College serves many more of these students (74 percent) in comparison with Brookhaven College (57 percent), with Eastfield College and Trinity Valley Community College in the middle (66 and 69 percent, respectively). The colleges also differ markedly in their racial and ethnic makeup, with El Paso Community College serving a primarily Hispanic population (85 percent), Trinity Valley Community College a majority white population, and Brookhaven and Eastfield a more mixed population. The majority of the enrollees at all of the colleges are part-time students; however, Trinity Valley Community College and El Paso Community College have larger proportions of full-time enrollees than Brookhaven College and Eastfield College.

Student Sample

Students were enrolled in the study in four cohorts from the fall 2015 through spring 2017 semesters.[32] A total of 1,411 students were enrolled in the study; 83 percent of them were assessed as two or more levels below college-ready, and thus typically needing to take two or more developmental math courses. (See Table 1.2.) Students tended to be young (average age of 23 years), female (over 50 percent), and Hispanic (54 percent of the sample). Most of the students planned to enroll full time, and nearly a third of the sample had failed a high school or college math class.

The biggest difference between the schools' general populations and the study sample was in the proportion of students who enrolled full time: Most of the sample (61 percent) planned to enroll full time compared with a range of 15 to 44 percent in the schools overall. (See Table 1.1.) This difference may have been in part the result of the data used to estimate enrollment: The school population data are based on national data from IPEDS, while the study sample's baseline characteristics come from students' self-reports on a baseline survey. Students' definition of "full time" and "anticipation of enrollment" may also have differed from their actual status.

In comparison with the colleges' overall student population, the study sample had fewer males. Additionally, though the sample was racially diverse, there were fewer black students and students who reported as other races or ethnicities than in the colleges' student bodies. Data were not available to estimate the size of the population at each college that was identified as having developmental needs. However, previous research has shown that large portions of students entering two-year and four-year colleges are placed into and required to take developmental math courses, making this study relevant for many college populations.[33]

Data Sources

CAPR's evaluation of the DCMP relied on multiple data sources to analyze the program's implementation, impact, and costs. The analyses in this report rely primarily on the data sources described below.

---

[32]For one college, only the first three cohorts were randomized and included in the study.

[33]Bailey, Jeong, and Cho (2010); Chen (2016).

Table 1.2

Baseline Characteristics of Full Sample, by Site

Characteristic	Brookhaven	Eastfield	El Paso	Trinity Valley	All Colleges
Age (years)	24.0	21.1	23.5	22.3	22.5
Male (%)	33.3	37.6	17.5	37.5	30.6
Missing	6.3	12.6	5.6	5.8	8.0
Race/ethnicity (%)					
White	7.9	7.4	6.3	33.1	13.7
Black	12.7	17.4	0.9	21.5	12.6
Hispanic	61.1	54.1	82.5	15.7	54.1
Other	6.3	2.0	1.3	2.5	2.3
Missing	11.9	19.1	9.1	27.3	17.3
Planned full-time enrollment (12 credits or more) this semester (%)	37.6	51.4	62.0	79.9	61.2
Has failed a high school or college math class in the past (%)	50.0	28.0	31.4	28.1	31.1
Missing	2.4	12.8	4.3	4.7	7.0
Math placement[a] (%)					
College-ready or exempt	7.1	2.0	1.5	3.3	2.6
Placed 1 level below college-ready	21.4	4.1	16.5	17.6	13.2
Placed 2 levels below college-ready	71.4	93.9	79.0	79.1	83.2
Placed 3 levels below college-ready	0.0	0.0	3.0	0.0	1.0
Enrolled within 12 months of high school graduation (%)	68.3	70.1	67.5	69.5	68.9
Sample size	126	460	462	363	1,411

SOURCE: CAPR calculations using data from a baseline survey of students participating in the study and administrative student data. The students completed the baseline survey immediately before random assignment, during the study intake process.

NOTES: Rounding may cause slight discrepancies in sums and differences.
Missing values are only shown for items with more than 5 percent missing values
[a]While course names vary among colleges, math courses three levels below college-readiness are frequently referred to as "Pre-Algebra" or “Early Math.” Similarly, courses two levels down may be referred to as "Beginning Algebra," and courses one level down may be referred to as "Intermediate Algebra."

Baseline Data. A baseline survey was given to students immediately before random assignment and asked students for general academic information such as the last grade of school completed, intended major, the number of credits they intended to take, and whether they had failed a math class previously. The baseline survey also included six questions asking students about their perspectives on math and math learning, such as confidence with math and their use of math in everyday life.

College Demographic Data. The colleges shared data on students’ race, ethnicity, and gender with CAPR researchers. This information was used to understand the demographic characteristics of the students in the sample and compare it with the overall student population at each of the study colleges.

College Placement Test Data. The colleges also shared data on students' placement test scores with researchers. They used this information to understand students' math placement level at the beginning of the study, which was used for some subgroup analyses.

College Transcript Data. The colleges provided CAPR researchers with information on students' course taking, course completion, and degree receipt. At least three semesters of data are available for each of the four cohorts, beginning with the first semester after random assignment. Four semesters of data are available for the first three cohorts. Chapter 4 uses these data to analyze the DCMP's effect on student outcomes.

Student Records from the National Student Clearinghouse (NSC). The NSC is a nonprofit organization that collects and disburses information on students' enrollment and degree or certificate receipt from more than 3,500 colleges across the country. These colleges enroll more than 98 percent of the nation's college students. NSC data are available for at least three semesters for all sample members, and four semesters for the first three cohorts. Chapter 4 uses these data to analyze enrollment and degree receipt across institutions.

Field Research. Throughout the four semesters of the study, CAPR researchers conducted site visits to each of the colleges to better understand the institution-level and classroom-level implementation of the DCMP. Site visit activities consisted primarily of interviews with faculty, staff, and administrators; focus groups with students; and classroom observations. Primarily, these activities involved collecting instructional data on the DCMP and standard developmental and college-level courses in order to analyze the fidelity and contrast in instruction in these courses. Research staff also interviewed administrators, advisors, and student support services staff members to understand how the colleges revised institutional policies to support the implementation of the DCMP.

Student Survey. All students in the sample were sent a second survey toward the end of their first semester after random assignment.[34] They received the survey online initially; those who did not respond got phone calls. The survey asked students currently taking a math class about the class's content, instruction, and level of difficulty. The survey also asked all students about their perspectives on math and math learning. The response rate for the survey was 71 percent in the program group and 70 percent in the standard group. Chapter 3 uses these findings to discuss the fidelity and contrast between the DCMP and standard math courses, and the DCMP's impact on students' perspectives on math.

Limitations of the Study

As Chapter 2 describes in more detail, the CAPR evaluation of the DCMP focuses on how revisions to content and pedagogy and how the acceleration of developmental math affected student outcomes. The DCMP curricula are explicit in helping teachers implement more small-

[34]The first cohort (fall 2015) of students received the survey toward the end of their second semester of the study (spring 2016). Unlike the other cohorts, these students were asked questions regarding their math class in the previous semester.

group, active-learning-based instructional models within the DCMP classes, a pedagogical tenet that may or may not occur in other math pathways models. As such, students' experiences in the DCMP classes in this study may not be representative of students' experiences in other math pathways or even DCMP courses at other colleges outside of this study.

Additionally, given the relative newness of the DCMP and the intensive nature of preparation needed to implement the courses, this study was not able to randomly assign teachers to lead the DCMP courses. Teachers who taught the DCMP classes tended to be full-time faculty, while a range of faculty, including both full-time and adjunct employees, taught other math classes. Given their full-time status and experience teaching, it is possible that the faculty teaching the DCMP courses were stronger than instructors teaching other math courses.

Finally, few measures exist to document student learning in higher education, making it difficult to do a deep investigation of course content and learning outcomes, such as examining the actual skills that students learned in each class. Additionally, the content of the DCMP courses is different from that of the colleges' standard courses, making it challenging to compare what students have learned and its applicability to their success in other college courses and in their careers. This makes it more difficult to assess the validity of critics' claims that math pathways courses are less rigorous than colleges' standard courses. However, the study hopes to address some of these challenges by examining students' accumulation of credits to consider the applicability and utility of the math that students learned. If students in the DCMP courses make measurable progress in accumulating college credits and ultimately completing college, then it is reasonable to conclude that the instruction they received is not impeding their success in college.

Structure of the Report

The remainder of this report is divided into five chapters. Chapter 2 discusses in more detail the DCMP model and expectations for its implementation. Chapter 3 discusses the implementation of the DCMP at the four colleges, and the fidelity and contrast between the DCMP and the colleges' standard math courses. Chapter 4 analyzes the DCMP's impact on students' outcomes. Chapter 5 examines the costs of the DCMP. Finally, Chapter 6 provides concluding thoughts and recommendations for next steps in research and practice.

Chapter 2

The Design of the DCMP and Expectations for Implementation

As discussed in Chapter 1, the use of the math pathways model has become a popular reform to improve developmental students' math outcomes. While math pathways models differ across the country, many colleges contend with similar challenges in implementing these new approaches. For instance, they must revise their math requirements for each major and educate advisors, faculty members, and staff members about them. They must also change advising practices so that advisors can direct students to the appropriate course based on their intended program or major. Additionally, community colleges must consider whether these courses will transfer seamlessly to their partner four-year colleges, ensuring that students will not be required to retake their math courses. Finally, colleges must ensure they have faculty equipped to teach the new math pathways courses or be ready to train current staff members in their implementation. Any misstep in these implementation milestones may hinder colleges' ability to appropriately scale their math pathways courses to serve the full college community.

This chapter describes the specific foci of the Dana Center Mathematics Pathways (DCMP) model, the supports that the Dana Center has provided to help colleges implement these pathways, and the implementation expectations for the four colleges that participated in this study. It describes both the Dana Center's broad vision for the DCMP, based on four key implementation principles, as well as the specific curricular models that the Dana Center designed in order to assist colleges in changing course content and pedagogy. The chapter concludes with a discussion of the specific DCMP models that the colleges in this study planned to implement as well as a brief summary of the supports they received. This information will serve as a backdrop for Chapter 3, which discusses the colleges' implementation of the DCMP, their fidelity to the DCMP model, and how these new courses compared with colleges' standard algebra-focused math courses.

Key points from the chapter include:

- The DCMP is based on four central principles that encourage colleges to implement diverse math sequences that align with students' majors and allow them to complete a college-level math course in one year, regardless of their developmental education status. The principles also encourage strong supports for student learning and the integration of evidence-based practices in classrooms.

- The Dana Center developed specific curricula for three pathways, which begin with an accelerated developmental math course appropriate for all three pathways and curricula for college-level classes in statistics, quantitative reasoning, and a path to calculus, respectively. Each of these curricula integrates more contextualized, student-centered learning models for both developmental and college-level math classes.

- The four colleges in the study were expected to revise their institutional policies to support the growth of the DCMP on a larger scale and implement the DCMP curriculum in an accelerated developmental math course. While curricula were also available for implementing college-level math courses, colleges' implementation of these curricula was relatively limited. As such, it was expected that program group students would primarily take the colleges' standard college-level statistics or quantitative reasoning courses after completing the DCMP developmental math course.

- The colleges in the study received supports from the Dana Center and researchers from the Center for the Analysis of Postsecondary Readiness (CAPR) in order to more fully scale the DCMP courses at their institutions.

The Design of the Dana Center Mathematics Pathways

The Charles A. Dana Center at the University of Texas at Austin launched the DCMP (formerly the New Mathways Project) in 2011 with the support of the Texas Association of Community Colleges (TACC). Building on their former work with the Carnegie Foundation for the Advancement of Teaching in developing Statway and Quantway, the Dana Center was interested in creating a scalable multiple math pathways model that could be adapted across diverse college settings. The Dana Center's work with the TACC helped it cultivate a larger political and state environment that fostered an agreement from all 50 community colleges in the state in 2012 to implement the DCMP model. Through this work, the Dana Center and TACC, along with the Texas community colleges, sought to fundamentally alter Texas's developmental and introductory college-level math course sequences as well as the state math policies for both two-year and four-year colleges.[1]

In order to ensure that the DCMP was scalable, the Dana Center focused on a broad set of principles that colleges could use to guide their implementation. The four main principles underlying the model are:

1. **All students, regardless of college readiness, enter directly into mathematics pathways aligned to their programs of study.** States and institutions review major offerings and identify a small set of math pathways that best align with their programs. Faculty and state leaders develop course learning outcomes for students' first college-level ("gateway") math courses that align with recommendations from research, the field, and professional associations. Colleges and states work to develop statewide or regional agreements to align course pathways across institutions. Advisors adapt their guidance to support students' enrollment in appropriate math pathways courses.

[1]Dana Center Mathematics Pathways (n.d. [b, d]).

2. **Students complete their first college-level mathematics requirement in their first year of college.** All students are required to take math in their first year in college, and college leaders employ strategies to reduce attrition across semesters, such as encouraging them to take their required math courses in the following semester and pre-registering them for courses.

3. **Strategies to support students as learners are integrated into courses and are aligned across the institution.** College leaders encourage classroom instructors to incorporate activities that support and engage students in their learning and help them develop the attitudes that will foster their success in college. Student support staff and others at the college also employ strategies that encourage student success, such as regular check-ins with students, tutoring, or other supports. Faculty and staff members are invested in this work and support its implementation across the institution.

4. **Instruction incorporates evidence-based curriculum and pedagogy.** Math faculty members develop standards that will guide their instructional practice, and institutional leaders provide supports to help faculty members to meet these standards and continuously improve their instruction. The Dana Center advocates for classroom instructional practices and curriculum design that provide opportunities for students to actively engage in problem-solving with their peers around challenging mathematics content. The Dana Center encourages instructors to contextualize math learning in real-life situations, and students to build their ability to communicate about their math learning.[2]

The Dana Center developed these principles to be broad enough to encompass the many different versions of math pathways that colleges may need to implement to meet their institution's needs.

In Texas, the Dana Center worked statewide to support policy changes that would enable colleges to more easily implement the DCMP. For instance, Dana Center staff members met with a number of Texas community college and university organizations, such as the Texas Council of Chief Academic Officers, the Council of Public University Presidents and Chancellors, and the Community College Initiative, to inform stakeholders about the DCMP and its implications for two-year and four-year institutions.[3] They worked with the Texas Higher Education Coordinating Board (THECB) to consider appropriate changes to state policies on developmental math completion, developed inventories of math requirements by program for all the state's public colleges, and hosted meetings between two-year and four-year colleges across the state to promote the alignment of institutional policies and program requirements.[4] Each of these resources

[2]Dana Center Mathematics Pathways (n.d. [c]).
[3]Charles A. Dana Center (2014).
[4]Dana Center Mathematics Pathways (2014b); Dana Center Mathematics Pathways (2017b).

and activities was designed to help promote the scalability of the DCMP across multiple state institutions.

The Dana Center is now heavily involved in promoting the implementation of the DCMP across the nation and works with more than 15 states to help them implement multiple math pathways.[5] It seeks to work across multiple levels of the system, including the development of national and state policies that will help promote the implementation of the DCMP at the institutional and classroom levels.

The DCMP Curricular Models

Dana Center staff members recognize the challenges inherent in integrating new curricula and pedagogies into classrooms. Therefore, they developed curricular tools that colleges could use to support the revision of these courses and to create their own courses aligned to the DCMP principles. These curricula are focused on developmental and introductory college-level math courses, divided across the three math pathways that are aligned with students' intended careers. (See Figure 2.1.) These include a statistics pathway, for students entering social and health sciences; a quantitative reasoning pathway, for students entering careers in the humanities; and a path to calculus for students in science, technology, engineering, and mathematics (STEM) majors.[6]

Similar to Statway and Quantway, the DCMP curricular models focus on implementing revised content and pedagogical strategies within developmental and college-level math classes. The DCMP curricula begin with a revised and accelerated developmental math course, Foundations of Mathematical Reasoning, which combines two separate developmental courses into one course that applies to all three math pathways. First, the course is accelerated, replacing two semester-long developmental courses (typically Beginning Algebra and Intermediate Algebra) with a one-semester course integrating algebraic, statistics, and quantitative literacy content. Although the DCMP is open to students with multiple developmental needs, Foundations was originally designed to allow students assessed as needing two developmental courses to complete these requirements in one semester.[7] Additionally, unlike standard developmental math courses, which tend to focus primarily on algebraic concepts such as linear equations, exponents, and manipulating formulas,[8] Foundations emphasizes these concepts along with the

---

[5]California, Georgia, Maine, Maryland, New Mexico, Colorado, Indiana, Missouri, Montana, Nevada, Ohio, Arkansas, Massachusetts, Michigan, Oklahoma, and Washington, and North Carolina (Dana Center Mathematics Pathways, n.d. [d]).

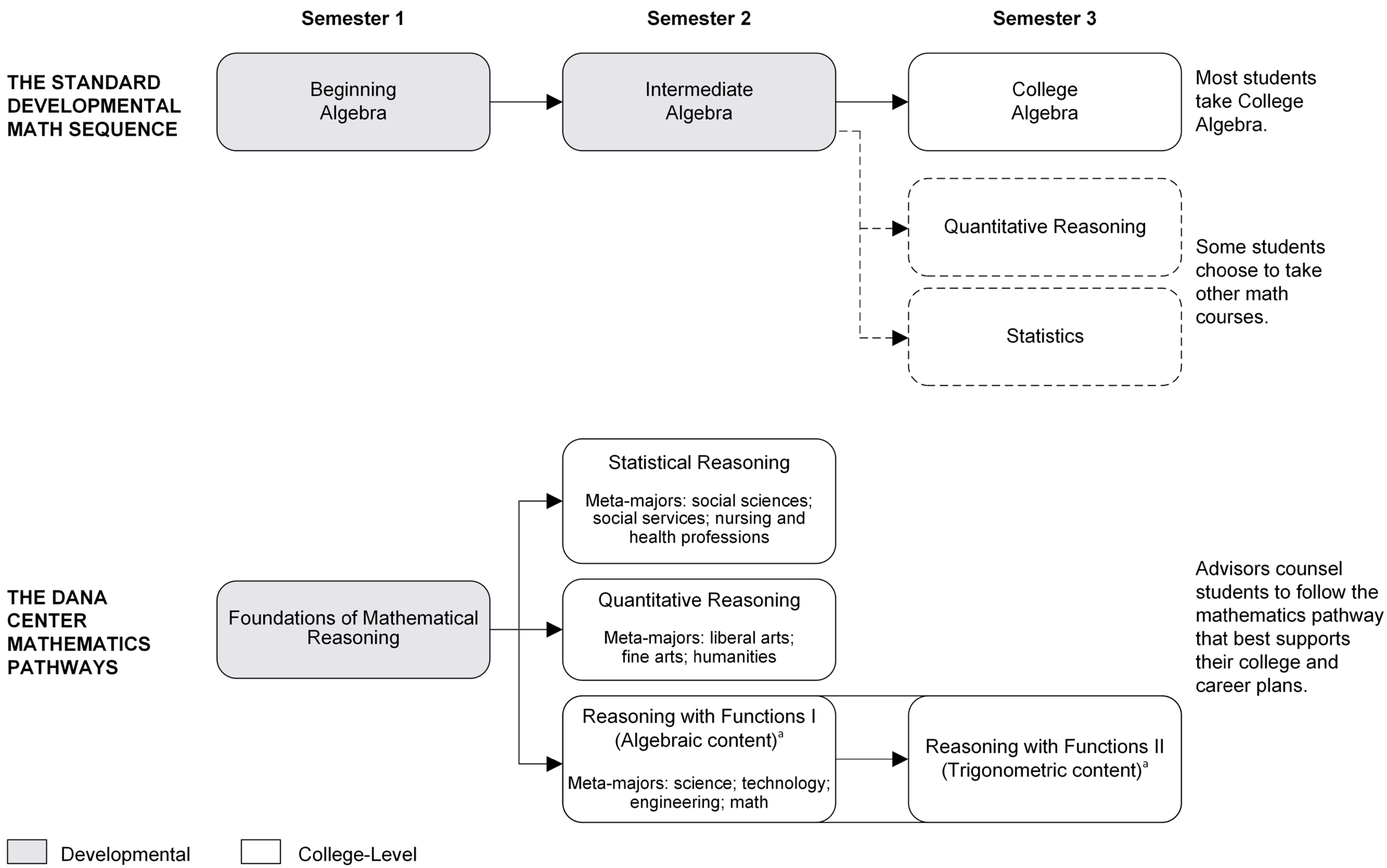
[6]The DCMP also includes a student success course (Frameworks for Mathematics and Collegiate Learning) aimed at helping students develop skills as learners. However, the study colleges offered few to no Frameworks courses using the Dana Center's curriculum, and thus it is not part of the program under study.

[7]Generally, entering students are assigned to take developmental courses based on their scores on the Texas Success Initiative Assessment or their ACT or SAT scores. Those scoring below a certain cutoff score, as determined by the state, are deemed not college-ready and are recommended to take one or more levels of developmental courses, which must be completed before entering college-level courses.

[8]Stigler, Givvin, and Thompson (2010).

Figure 2.1

A Comparison of Mathematics Courses for Students with Two Levels of Developmental Need



NOTE: [a]Evaluation of Reasoning with Functions I and II is outside of the scope of this study.

development of students' numeracy and statistics skills. The DCMP allows colleges the flexibility to implement their own, internally developed models for math pathways courses, but all the colleges in this study implemented Foundations.

Finally, Foundations integrates contextualized, student-centered learning approaches, which are grounded in current research on effective mathematics instruction and articulated in the Dana Center's eight curriculum design standards for math courses. (See Table 2.1.)[9] These standards encourage students to work closely with one another to solve math problems embedded in the context of real-life situations. Rather than presenting students with formulas or algorithms, DCMP students are expected to wrestle with larger mathematical ideas and apply previously learned concepts in multistep math problems that are often in a narrative, or require students to dissect and compare math figures, graphs, or tables (as shown in Box 2.1). Within the curricula and in trainings on the DCMP, instructors are encouraged to promote students' constructive perseverance — their ability to struggle through challenging concepts and understand the role that struggle plays in learning. Course materials integrate content from other academic disciplines, such as finance, civic literacy, and science, and students are expected to develop multiple strategies for solving complex mathematical problems. Additionally, the course seeks to develop students' reading and writing skills more fully; they are routinely engaged with word problems and asked to provide written explanations of their solutions. Finally, they are encouraged to regularly engage with technology, including the use of calculators and a computer-based learning platform to complete homework assignments.[10]

These types of instructional approaches differ markedly from the approaches often used in standard developmental math courses, most of which are heavily focused on algebra with content primarily taught through lecture rather than more student-centered approaches. (See Table 2.1.)[11] Traditionally, instruction tends to revolve around procedural understandings of algebraic content, often through the memorization of particular formulas or rules for solving equations with little to no real-world applications.[12] Finally, any writing or reading, if present, tends to take place through note-taking or textbook reading, respectively. The pervasiveness of technology varies, though it has become more prevalent as the use of computer-based learning platforms such as MyMathLab increases.[13]

Upon the successful completion of Foundations, students in the DCMP curricular pathways enter a one-semester, college-level statistics (Statistical Reasoning) or quantitative reasoning

---

[9]For examples of current research on effective mathematics instruction, see, for instance, Mesa, Celis, and Lande (2014); Hiebert and Grouws (2007); Richland, Stigler, and Holyoak (2012); American Mathematical Association of Two-Year Colleges (2018); Saxe and Braddy (2015); Crawford (2001). For the Dana Center's eight curriculum design standards for math courses, see Charles A. Dana Center (2017a).

[10]Dana Center Mathematics Pathways (2017a).

[11]Grubb (2013).

[12]Hiebert and Grouws (2007); Richland, Stigler, and Holyoak (2012); Givvin, Stigler, and Thompson (2011); Stigler, Givvin, and Thompson (2010).

[13]Epper and Baker (2009); Zachry Rutschow and Mayer (2018).

Table 2.1

Key Distinctions Between Standard Math Courses and DCMP Courses

Program Component	Standard Math Courses	DCMP Courses
Course Structure		
Course sequence	The number of courses required depends on the student's level of developmental need.	Students with one or two levels of developmental need take only one developmental course.
Math content	Developmental courses emphasize algebraic skills and are designed to lead to college-level algebra.	The developmental course emphasizes quantitative literacy, statistics, and algebraic reasoning skills. College-level courses are diversified based on major.
Instruction and curricular materials		
Curricular materials	Varies; traditionally, the curricula focus on discrete skills and topics.	Curricula are organized around broad mathematical concepts and big ideas.
Pedagogical approach	Varies; traditionally, classes are lecture-based.	Instruction employs a variety of approaches including small-group work, class discussions, and interactive lectures. Students are actively involved in analyzing data and problem-solving.
Constructive perseverance	Varies; this is not a focus in standard math instruction.	Students develop metacognitive skills such as the ability to work through challenging tasks and self-monitor learning.
Problem solving	Varies; traditionally, students learn formula-based applications and rote practice using one solution method.	Instruction supports applying previously learned skills to unfamiliar and nonroutine problems; students develop multiple strategies and solution methods.
Context and interdisciplinary connections	Varies; generally, the use of formulas, equations, and symbols are taught as discreet skills.	Math problems are contextualized around real-life situations and/or integrate academic disciplines; curricula use real data sets and incorporate realistic applications.
Reading and writing	Varies; there are traditionally some word problems. Class is focused on equations and rote practice in applying formulas.	Students develop the ability to read about math and explain solutions in writing.
Use of technology	Varies; instruction is traditionally textbook-based. There is limited use of calculators.	Students regularly use calculators and computers in class and at home

SOURCE: Dana Center Mathematics Pathways (2017a).

Box 2.1

DCMP Foundations Lesson 14, Part A

The body mass index (BMI) is a measure of body fat based on height and weight. It is a standard tool for helping judge the amount of body fat you have. Carrying excess body fat puts people at greater risk for health problems such as heart disease, cancer, diabetes, and stroke. BMI can be calculated using a simple ratio based on a person's height and weight. Your BMI is considered to be in the normal range if it is between 18.5 and 25.

1. BMI is considered a better predictor of health than weight alone. Jot down your ideas about why this statement would be true, then share with another student.

BMI can be calculated with the following formula, where the weight is in pounds and the height is in inches.

$$\text{BMI} = \frac{\text{Weight}}{\text{Height}^2} \times 703$$

2. Joe is 5 feet, 10 inches tall. Substitute his height into the formula.
3. You have created a new formula that applies only to people who are Joe's height. What are the only variables that remain in your new formula?
4. Using your simplified formula, calculate Joe's BMI if he weighs 175 pounds. How does Joe's BMI change if he gains 10 pounds? If he loses 10 pounds?
5. Discuss with your group how you arrived at Joe's BMI value. For example, did you multiply, add, subtract, etc., and what did you do first? Outline the steps you took to calculate the BMI when given the height and weight. Be specific.

(Quantitative Reasoning) course or begin a two-semester path to calculus with Reasoning with Functions I in the first semester followed by Reasoning with Functions II the following semester, as shown in Figure 2.1. For these courses, the Dana Center developed curricula emphasizing similar types of student-centered learning approaches as those integrated into Foundations.[14] The content of the courses also aligns with the learning outcomes designated for statistics and quantitative literacy courses in the THECB's *Academic Course Guide Manual*, the official list of courses that Texas's community colleges can offer with state funding. Students who successfully complete Statistical Reasoning or Quantitative Reasoning have generally met the transferable, college-level math requirement for their major; however, students pursuing STEM majors typically need two semesters to complete their entry-level math requirements before they become ready for calculus or the other higher-level math courses required by their majors.[15]

---

[14]Charles A. Dana Center (n.d. [b]).

[15]Texas Higher Education Coordinating Board Academic Course Guide Manual (2019); Charles A. Dana Center (2018).

Nine Texas colleges originally piloted the Foundations curriculum in fall 2013, followed by the Statistical Reasoning curriculum in spring 2014 and the Quantitative Reasoning curriculum in spring 2015.[16] The Dana Center has since adapted and revised these curricula based on colleges' experiences and the implementation of new state policies. At least 40 colleges across the country have piloted and implemented these curricular models as of fall 2017. In 2017, the Texas legislature passed a law that required all public colleges to enroll developmental students into corequisite courses (college-level courses paired with a developmental support course), with a gradual scale-up of these models to 75 percent of classes by 2020. The Dana Center has been active in developing revised curricular models for their statistics and quantitative reasoning pathways that incorporate corequisite supports.[17]

Creating Conditions for a Fair Test of the DCMP

CAPR researchers sought to evaluate how changes to content and instruction might affect student outcomes, including their completion of developmental math and college-level math courses, accumulation of credits, and completion of a credential or degree. Therefore, the research team looked for colleges that (1) were prepared to invest in faculty training and to take other steps to ensure the curriculum was fully implemented; (2) did not have many competing initiatives, such as other large-scale reforms to developmental math courses, that would potentially complicate the impact study (particularly with respect to the standard group); and (3) could meet the sample requirements.

Given these considerations, CAPR researchers identified several aspects of the DCMP model that would be important to test as part of the evaluation. First, the team sought to identify colleges implementing statistics and/or quantitative reasoning math pathways with a one-semester accelerated developmental math course following by a college-level statistics or quantitative reasoning course in the second semester.[18] Ideally, the team hoped to identify colleges that were implementing the Foundations curriculum with developmental students and the DCMP curricula in college-level statistics and quantitative reasoning courses. Third, the team searched for colleges implementing the more student-centered, contextualized pedagogical strategies encouraged by the DCMP curricula. The team also hoped to find sites that were implementing more intentional student success supports that helped students develop the skills and attitudes to become independent learners, such as the ability to monitor their own learning.

In addition to identifying colleges that were implementing these aspects of the DCMP curricular models, the team hoped to identify colleges with developmental course offerings that provided a strong contrast to the DCMP. As such, the research team looked for colleges that were not implementing other developmental reforms, such as developmental math course acceleration, across a large number of courses at the institution. Additionally, CAPR researchers planned to

[16]Zachry Rutschow and Diamond (2015).

[17]H.B. 2223, 85th Legislature, 2017-2018 (Texas 2017); Dana Center Mathematics Pathways (n.d. [a]).

[18]The STEM-prep pathway and Reasoning with Functions I and II curricula had not yet been developed by the start of the study. As a result, evaluation of this pathway is beyond the scope of this study.

partner with colleges that could contribute to the relatively large sample size requirements for a randomized controlled trial, which requires approximately 1,000 students or more, and thus searched for colleges that had scaled or were planning to scale the DCMP at a relatively high level across their institutions.

After an introduction by Dana Center staff members, the CAPR research team contacted more than 40 colleges about the study and met with 13 colleges about participating in the study.[19] In initial discussions, the team investigated each college's level of DCMP implementation, the courses and curricula that they used, the level of faculty and staff support for the DCMP, and the level of contrast with the college's standard course offerings. Many initial contacts did not meet the original criteria because they had scaled math pathways across their institution and thus had little service contrast; were not implementing the DCMP or were implementing the courses in very limited numbers (for example, only one or two sections); did not have strong faculty and staff support; had other highly scaled developmental math reforms that would reduce the service contrast with the DCMP; were not implementing content and curricula aligned with the DCMP curricular model; or were not interested in participating in an evaluation.

Given the challenges identifying sites, the research team modified the site selection criteria, expanding the search to colleges that were not necessarily implementing the DCMP's revised pedagogical approaches in their college-level statistics or quantitative reasoning classes. The colleges selected for the study were implementing one or two sections of statistics or quantitative reasoning courses using the DCMP curricula; however, by and large, their standard courses made up most of their course offerings in these subjects. As such, students assigned to the program group in the study would have the opportunity to receive revised instructional models in their developmental course but could enroll in the colleges' standard college-level statistics or quantitative reasoning courses, which may or may not have employed these instructional principles. Additionally, the team included colleges that were not necessarily implementing intentional student success strategies in conjunction with DCMP courses, although the colleges were offering student supports to their general student population. With these modifications, the CAPR research team recruited four colleges to participate in the study.

Supporting DCMP Implementation

CAPR researchers and the Dana Center also provided support prior to and during the study to help participating colleges' implementation and scaling of the DCMP. First, the Dana Center offered a wide range of training and other professional development resources to all colleges implementing DCMP curricula, including a three-day training on the DCMP curricula in three consecutive years (2013, 2014, and 2015). The curricula developed by the Dana Center also provide implementation supports for instruction, including lesson and course sequencing and suggestions for how to structure and facilitate each lesson. Additionally, the Dana Center set up an online community for DCMP instructors to share lessons and tips for implementation and developed

[19]Among the 40 colleges that the research team contacted, some were individual campuses that were a part of a large community college system.

opportunities for mentoring and supports from colleges experienced in implementing the DCMP through both in-person and virtual meetings. The Dana Center's staff members were also available for support, including a teaching ally, or mentor, who was available for individual meetings with faculty members. During the time of this study, Dana Center staff members also visited each college to provide support at least once during implementation of the DCMP.

Additionally, both CAPR researchers and Dana Center staff members provided specific supports to colleges participating in the randomized controlled trial. These supports focused on helping colleges develop systems and policies to implement the DCMP at an institutional level, including assisting the colleges with revising their internal majors and math requirements (based around the Dana Center's recommendations) so that statistics and quantitative reasoning courses could fulfill students' math requirements in selected majors. Second, CAPR researchers supported colleges in targeting and recruiting students by helping colleges estimate and plan for the number of potentially eligible students and develop advising mechanisms to determine the students' eligibility. Finally, CAPR researchers and the Dana Center assisted the colleges in one-on-one negotiations with their four-year transfer partners to ensure the alignment of math policies across institutions. For instance, CAPR researchers and Dana Center staff members negotiated math policies with a variety of four-year college leaders and faculty in specific disciplines to encourage their use and acceptance of non-algebra courses for specific majors. Additionally, they helped colleges develop written agreements that ensured students taking DCMP courses would not be required to take developmental and college-level algebra courses upon transfer to four-year partners.

The DCMP Model Evaluated in This Study and Its Theory of Action

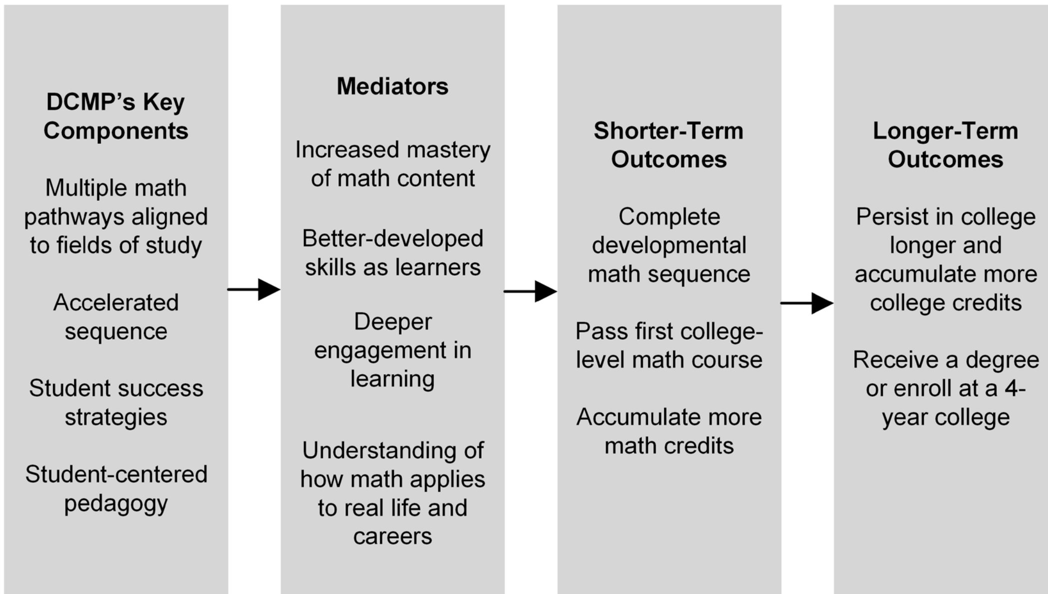
All four colleges participating in the study implemented or planned to implement the accelerated and revised DCMP developmental Foundations course. In addition, all participating colleges implemented at least one DCMP Statistical Reasoning or Quantitative Reasoning course. However, given the limited scale of these courses, students in the program group who successfully passed the Foundations course were offered the opportunity to enroll in the colleges' standard statistics or quantitative reasoning courses.

As such, the DCMP model in this study can be considered a two-semester, two-course intervention. The intervention includes instructional and content changes in students' first semester. For those assessed as needing at least two semesters of developmental math, the DCMP also serves as an opportunity to accelerate their progress through developmental math and into a college-level math course. In the second semester, the intervention includes revised content in the college-level math course, as students are offered the opportunity to take a statistics or quantitative reasoning course to fulfill their math requirements rather than college algebra.

As shown in Figure 2.2, the researchers' expectation was that the Dana Center and college inputs would enable colleges to make the changes necessary to implement the DCMP

Figure 2.2

The DCMP Model's Theory of Action as Evaluated in This Study



at the institution and classroom levels. These activities would include developing accelerated multiple math pathways and courses that align with students' careers (institution level) as well as classroom content (all math courses) and instructional changes (developmental courses only). These activities would lead students to better understand how math applies to their lives and careers, help them master math content, and be more engaged in their math courses. These outputs are expected to contribute to students' successful completion of their developmental math requirements in one semester and their completion of a college-level math course in one year (short-term outcomes). In the longer term, the DCMP is expected to contribute to students' accumulation of credits and, ultimately, transfer or graduation. A fuller discussion of these outcomes is provided in Chapter 4.

Given that these interventions occurred simultaneously, this study is unable to disentangle the effects of acceleration, math content changes, and reforms to instruction. However, it does seek to provide a more in-depth analysis of instruction than has been provided in previous studies as well as an examination of whether these changes affected students' experiences in the classroom.

Chapter 3

Implementation of the Dana Center Mathematics Pathways

This chapter describes the fidelity of the four colleges' participating in the evaluation by the Center for the Analysis of Postsecondary Readiness (CAPR) of the Dana Center Mathematics Pathways (DCMP) in implementing the program model at both the institution and classroom levels. The analysis is based on a combination of data from classroom observation, focus groups with students attending the courses observed, and interviews with the course instructor about the content and pedagogy as well as interviews and focus groups with math faculty, deans and department chairs, advisors, administrators, math tutors, and institutional researchers. Additionally, it reports results of a survey that was disseminated to most students in the study during their first semester after random assignment, when program group students would have the opportunity to enroll in the DCMP program.[1] The key findings from this chapter are:

- Most colleges implemented the DCMP with fidelity at the institutional level, although some challenges remained with advising and the alignment of math requirements with four-year transfer partners.
- Both developmental and college-level courses using the DCMP curricula were implementing the DCMP curricular model with strong fidelity, despite a few challenges with the implementation of active learning, constructive perseverance, and reading and writing early in the study.
- Classes using the DCMP curricula, including Foundations of Mathematical Reasoning, Statistics, and Quantitative Reasoning, contrasted strongly with colleges' standard developmental and college-level algebra courses.
- Although most students liked their math classes and instructors, program group students had strikingly different experiences in learning math from those of students in the standard group.
- Program group students demonstrated statistically significant differences in their understanding of how math applied to their everyday life. However, fewer than half of the students in either group reported feeling confident about math or enjoying their math learning.

[1]The study team fielded this survey to all cohorts near the end of their first semester in the study except the fall 2015 cohort. This cohort took the survey during their second semester and were asked to think about their math class from the previous semester when responding to questions.

Implementing the DCMP Model: Institutional Change

As Chapter 2 explains, effective implementation of the DCMP model required a number of institution-wide reforms. The colleges were expected to revise the math requirements for certain majors, align those majors with requirements at their four-year transfer partner colleges, and adjust advising practices to place students into the appropriate math pathway based on their intended career field. Additionally, because the colleges participating in the study used the DCMP curricular models, they needed to train and support faculty and academic advising staff to implement the DCMP's curricular courses and the necessary supports. The sections below describes the colleges' success in implementing these changes.

Revising Math Requirements

Over 80 percent of students in the study placed at least two levels below college-ready in math, meaning that most of these students would ordinarily need to pass at least two semesters of developmental algebra (Beginning Algebra and Intermediate Algebra), and then college algebra, before completing the math requirements for their degree program. However, in alignment with the key principles of the DCMP, each of the colleges in this study revised math requirements for humanities and social sciences majors, such that program students in those majors could take the DCMP developmental math course Foundations of Mathematical Reasoning, which is designed to accelerate the developmental math sequence and requirement to one semester. After the successful completion of Foundations, students in the program were then offered the opportunity to enroll in a college-level statistics or quantitative reasoning course in their second semester. Yet the extent of the revision of these math requirements by major varied across the colleges. For instance, one college shifted the math requirements for all non-STEM (science, technology, engineering, and math) associate of arts and associate of applied science degrees such that most students could take statistics or quantitative reasoning instead of college algebra; in contrast, another college revised only 30 of 160 possible majors recommended for a non-algebraically intensive pathway. Additionally, although each college implemented at least one statistics or quantitative reasoning course using the DCMP curricula, these courses were generally not scaled beyond one or two sections per semester. Most Foundations students who enrolled in a college-level math course signed up for standard offerings of college-level statistics or quantitative reasoning.

Transfer and Applicability of DCMP Courses at Partner Four-Year Colleges

Three of the four colleges participating in the study aligned their math curricula effectively with the majors and requirements at their four-year transfer partners prior to the start of the evaluation. This meant that DCMP students' math courses would transfer easily to a four-year institution, making it unnecessary to take additional developmental math courses. The study community colleges worked with a total of eight four-year partner colleges to align the math requirements across their degree programs.

Despite this coordination, a few challenges did remain throughout the study, often involving four-year colleges' wish to require a certain math course for their majors. In some cases, four-year colleges wanted to require academic area-specific statistics courses (for example, Statistics for Psychology Students), while a few colleges continued to require algebra for popular majors (such as nursing) that the Dana Center had recommended for a statistics or quantitative reasoning pathway. For these reasons, one college continued to have significant challenges with alignment to a primary four-year transfer partner throughout most of the study, though this college continued to successfully enroll students in the study in all four semesters.

Advising and Registration

All colleges modified their advising procedures to identify students' intended majors or careers to ensure that they could enter the appropriate math course pathway, a process they had not instituted widely prior to the study. This often happened through one-on-one discussions between advisors and students, although in some cases (such as during new student orientations), staff members spoke to students in eligible majors as a group to discuss the DCMP opportunity. At one college, advisors sent students to a specific advisor knowledgeable about the DCMP program who could review students' eligibility. To support this work, colleges often developed flow charts or tables that identified majors eligible for the DCMP, to assist advisors in placing students into the appropriate pathway. (See Appendix A for an example.)[2]

Advising did not always work as seamlessly as intended. First, as Chapter 1 notes, advisors tended to recommend fewer students to the DCMP than were eligible based on their majors, particularly in the first two semesters of the study. This was partially a result of the additional time advisors needed to identify students' majors, difficult during some busy registration periods. Another contributing factor was advisors' lack of clarity around the DCMP and its alignment with the math requirements at major four-year college transfer partners. Staff at two colleges also noted that students were unsure about the DCMP and how it would affect their transferability to four-year colleges. However, these issues improved over time.

Class Enrollment and Scaling

Partially because of the challenges outlined above in program enrollment, DCMP classes tended to be smaller than standard classes. DCMP classes had an average of 10 to 15 students, and approximately 20 percent of Foundations classes had seven students or fewer enrolled at the start of the semester. In comparison, the standard developmental math classes observed by CAPR researchers averaged 20 students.[3] Given that K-12 (kindergarten through twelfth grade) research has found class size to affect student outcomes, CAPR researchers asked students and instructors to reflect on how this may have affected their experiences. Smaller classes at times interfered with DCMP instructors' ability to implement active learning models in class. However, students' responses to class size varied, with some students' appreciating the greater level of attention they

---

[2]As previous chapters explain, the Dana Center's curricular models for a pathway to STEM programs were still in development at the time of the study. As such, the only students eligible for the DCMP were those pursuing majors that were eligible for a statistics or quantitative reasoning pathway.

[3]The standard developmental classes observed were not necessarily classes that students in the standard group were taking. Observations provided a general picture of standard developmental algebra classes.

received from their instructors, while others did not see class size as having an important influence on their classroom experience.

Colleges also offered the classes at various levels of scale that did not necessarily correspond with their student enrollment. For instance, one college with a relatively small student population regularly offered up to five sections of Foundations courses, whereas two larger colleges generally offered only two or three sections per semester. These differences in scale were often the result of the availability of faculty members to teach the courses and, in some cases, faculty members' or advisors' hesitations about offering the courses to large groups of students.

Professional Development

As Chapter 1 notes, teachers were not randomly assigned to teach the DCMP courses because of the limited number of instructors trained to use the DCMP curricula. Overall, instructors teaching the DCMP courses used multiple professional developmental supports to help them implement the revised courses. Virtually all DCMP faculty at the colleges had attended the Dana Center's multi-day training on the DCMP curricula. Additionally, instructors noted using and valuing the Dana Center's other supports, including mentoring by experienced colleges, the instruction guidelines included in the curricula, and the online community for DCMP instructors.

DCMP faculty members at three colleges also developed strategies for training and supporting new DCMP instructors at their own institutions. At one college, faculty members gave presentations on DCMP every semester, trained advisors, and developed in-house training for new DCMP instructors. This training involved close mentorship with experienced DCMP instructors that included observing DCMP classes and shadowing instructors to learn how to teach the course.

General Student Supports

As Chapter 2 explains, the DCMP model recommends integrating academic supports to help students develop the skills to be successful and independent learners as a complement to the student-centered learning classroom reforms recommended by the Dana Center. While each of the colleges had myriad supports available for students taking developmental education courses, including trained tutors and labs, the participating colleges tended to have some challenges adapting and expanding these services to help DCMP students at the beginning of the study. For instance, in interviews, some tutors were unfamiliar with the DCMP or discussed having challenges with supporting DCMP students because of their lack of familiarity with the DCMP curricula and its expectations. Another college noted that it lacked tutors trained in statistics, making it difficult to accommodate the larger flow of students needing assistance with statistics as a result of the program. As such, the higher-level student supports recommended as part of the DCMP model may have been weaker than the Dana Center recommended, particularly at the beginning of the study when colleges were just beginning to scale these pathways.

Summary

Overall, the colleges had relatively strong institutional-level implementation of the DCMP. The colleges made substantial changes to their institutional and academic policies as well as their advising mechanisms to support the scaling of these pathways. As a result, many students were ultimately enrolled in the study. Despite this, some challenges remained with recruiting many of the students who may have been eligible for the DCMP, aligning policies with four-year institutions, creating DCMP classes equivalent in number to standard developmental courses, and providing supports sufficient to accommodate DCMP students' needs. In most cases, the colleges ameliorated these challenges in later semesters as they gained experience with the DCMP, although some challenges such as alignment with four-year colleges and scaling the number of Foundations sections persisted at some colleges.

Fidelity and Service Contrast at the Classroom Level

The DCMP model in this study also required changes in the classroom. This section discusses the fidelity, or quality, of instructors' implementation of the DCMP's revised content and instructional models in developmental and college-level classes in relation to the Dana Center's eight curricular design standards, which are described in Chapter 2. The analysis also looks at the contrast between these courses and the colleges' standard developmental and college-level algebra courses. Figure 3.1 outlines the typical pathways for students in the program and standard groups. Program group students could take the Foundations of Mathematical Reasoning developmental course followed by either a college-level statistics or quantitative reasoning course. At most colleges, program group students would be offered the standard statistics and quantitative reasoning courses, although some colleges also implemented these courses with the DCMP curricula. Students in the standard group would take one or two developmental algebra courses, generally followed by college algebra.

The analysis in this section focuses on a combination of data gleaned from a classroom observation, a focus group with students attending the course observed, and an interview with the course instructors from the standard and program classes. Researchers asked students and instructors to reflect on what a typical course day looked like, whether the course the researchers observed was similar to other lessons, and their general perspectives on the class. Given limited resources, the researchers could not observe every developmental and college-level course that standard group students took, nor all the standard college-level classes that students in the program group took. As a result, the team observed a selection of these courses in order to consider how these courses as a whole compared with DCMP courses. Although researchers attempted to observe courses representative of those that standard group students took, there is a risk that the courses they examined were not typical of the colleges' courses or the courses that students in the study sample took.

This section also reports results from a student survey that researchers disseminated to students at the end of their first semester in the study, after program group students had the

Figure 3.1

Math Courses Offered to Study Participants

First Semester | **Second Semester** | **Third Semester**

PATHWAY FOR STANDARD GROUP STUDENTS

Beginning Algebra
(For students 2 levels below college-ready)
Covers algebraic concepts like solving linear equations, operations on real numbers, and polynomials. Introduces functions, graphs, fundamental operations on polynomials, and factoring.

→

Intermediate Algebra
(For students 1 level below college-ready)
Reviews elementary and intermediate algebra by topics necessary to prepare students to continue with more advanced courses in math. May include factoring, simplifying rational algebraic expressions, solving equations using rational expressions, and solving quadratic equations.

→

College Algebra
Provides in-depth study and applications of polynomial, rational, radical, exponential, and logarithmic functions and systems of equations using matrices. Builds on algebraic reasoning skills developed in high school or in the college's developmental sequence.
Number of classes observed/data collected: 8

Number of standard developmental classes observed/data collected: 16

PATHWAYS FOR PROGRAM GROUP STUDENTS

Foundations of Mathematical Reasoning
Surveys a variety of mathematical topics needed to prepare students for college-level math. Topics include numeracy, estimation, evaluating expressions and formulas, ratios and proportions, percentages, and linear models.

Number of classes observed/data collected: 19

→

Statistics
Covers the fundamentals of data collection, analysis, and interpretation.
Number of DCMP classes observed/data collected: 5
Number of standard classes observed/data collected: 9

→

Quantitative Reasoning
Organized around broad mathematical and statistical concepts such as modeling, probability, and statistics. Developed to help students gain skills meaningful for success in future courses, in the workplace, and as productive citizens.
Number of DCMP classes observed/data collected: 4
Number of standard classes observed/data collected: 6

Developmental (shaded)
College-Level (unshaded)

SOURCES: Course descriptions come from syllabi that CAPR researchers collected during classroom observations and the Texas Higher Education Coordinating Board's Academic Course Guide Manual (2019).

NOTES: The colleges involved in the study offered very few college-level classes using DCMP curricula; most program group students took classes using their colleges' standard curricula.

CAPR researchers did not collect data all developmental or college-level courses standard group students enrolled in, nor all college-level courses that program group students enrolled in. However, CAPR researchers took steps to collect data for courses representative of the courses study participants generally took.

opportunity to enroll in the DCMP developmental courses.[4] Students in both the program and standard groups were asked to answer questions about their experiences in their math courses and their perspective on math. The differences in their answers appear in tables throughout this section. For more information about how to read these impact tables, see Box 3.1.

Summary of Fidelity and Service Contrast

CAPR researchers examined study students' enrollment in college-level courses to see if they remained faithful to their respective program and standard math pathways, respectively. (See Appendix Table A.1.) As expected, most students in the program group took the DCMP Foundations courses while most students in the standard group took developmental algebra courses. Additionally, program group students who completed their developmental course requirements and enrolled in a college-level math class were more likely to take college-level statistics and quantitative reasoning, and/or some other non-college algebra math. Students in the standard group took more college-level algebra courses than program group students; however, a substantial proportion of standard group students also took statistics or quantitative reasoning

Box 3.1

Understanding the Impact Tables in This Report

The tables in Chapters 3 and 4 display the impacts of the DCMP program on students' experiences, behaviors, attitudes, and outcomes and use the format illustrated in the abbreviated table at the bottom of this box, which displays some hypothetical transcript data for the program and standard groups. The "credits earned" row shows that program group students earned an average of 9.1 Credits and standard group students earned an average of 6.1 credits.

The "Difference" column in the table excerpt shows the observed difference between the two research groups — that is, the estimated average impact of the opportunity to participate in the program. For example, the estimated average impact on credits earned can be calculated by subtracting 6.1 from 9.1, yielding an impact estimate of 3.0 credits earned. This difference represents the estimated average impact rather than the true average impact (which is impossible to determine) because, although study participants are randomly assigned to the program and standard groups, the impact estimate would have been different if a different sample of students had been included in the study or if the same group of students had been randomized in a different way.

Estimated effects marked with one asterisk or more are statistically significant, meaning that there is a high probability that the opportunity to participate in the program had an impact on that outcome measure. The number of asterisks corresponds with the p-value, which indicates the likelihood that an estimated effect at least as large as the one observed would have occurred

(continued)

[4]As mentioned in Chapter 1, students in the first cohort of the study (fall 2015) received the student survey in their second semester in the study (spring 2016) and were asked about their experiences in the math course they took in the previous semester.

Box 3.1 (continued)

by chance, if the true effect were zero (that is, if there were no true effect). One asterisk corresponds to a probability of 10 percent or less; two asterisks, 5 percent or less; three asterisks, 1 percent or less. In other words, asterisks (and thus statistical significance) indicate that it is likely that the DCMP had an effect (positive or negative) on that outcome. The more asterisks, the more likely that the opportunity to participate in the program had a true average impact on the outcome.

The impact in the table excerpt has three asterisks and a p-value of 0.008, indicating that the impact is statistically significant at the 1 percent level — meaning that there is less than a 1 percent chance of observing an estimated average impact this large (or larger) if the opportunity to participate in the program actually had no average effect on credits earned. In other words, there is a 99 percent level of confidence that the opportunity to participate in the program had a positive impact on the average number of credits earned.

Outcome	Program Group	Standard Group	Difference (Impact)	P-Value
Credits earned	9.1	6.1	3.0***	0.008

courses. As a result, there may have been less contrast in students' college-level math courses than expected by the DCMP model.

Overall, there was relatively strong fidelity to the DCMP curricula in Foundations, DCMP's Statistical Reasoning, and DCMP's Quantitative Reasoning. Instructors implemented most of the DCMP curricular design principles. (See Table 3.1 for a summary.) They consistently introduced math concepts using real-world examples, emphasized student-led problem-solving, and stressed the use of technology. Most instructors also regularly integrated reading, writing, and constructive perseverance strategies into their classrooms, although a handful of instructors had some challenges implementing these on a regular basis. Finally, active learning was also generally well implemented, although about a third of instructors had some challenges with this, particularly in smaller classes.

These practices contrasted sharply with the instruction in standard developmental and college-level algebra courses, which were primarily lecture-driven. Colleges' standard college-level statistics and quantitative reasoning were more likely to resemble DCMP curricular courses in their use of contextualized math problems, reading, and writing, although they also tended to be more lecture-driven. The sections below summarize how instructional practices looked in developmental and college-level courses using the DCMP curricula, and in standard developmental and college algebra courses. The next sections summarize how instruction differed in the colleges' standard statistics and quantitative reasoning courses.

Active Learning

Active learning, as Chapter 2 explains, refers to the active involvement of students in doing math — analyzing data, constructing hypotheses, and solving problems — and typically

Table 3.1

Comparison of DCMP Courses and Standard Developmental and College-Level Algebra Courses on Key Characteristics of the DCMP Curricular Model

Characteristic	**DCMP Curricular Courses** (Foundations of Mathematical Reasoning, Statistical Reasoning, and Quantitative Reasoning)	**Standard Developmental and College-Level Algebra** (Beginning Algebra, Intermediate Algebra, and College Algebra)
Number of classes observed	28	24
Number of distinct instructors observed	22	16
Active learning	Most classes devoted half or more of class time to activities such as small-group work, class discussions, and interactive lecture.	Primarily lecture-based. Two classes offered allotted time for extensive small group work.
Constructive perseverance	Most DCMP instructors allowed students to struggle with course material — they pushed students to consider other options and replied to students' questions with further questions. Some instructors stepped in quickly if they noticed students struggling.	Students are generally provided solutions to problems upon request, or as part of lecture.
Problem-solving	Students attempt multistep problems in small groups with limited guidance from instructors. Afterward, instructors offer opportunities for students to discuss their solutions. A few classes also encourage students to find different ways to solve problems.	Instructors demonstrate how to solve problems. If there is time, students solve problems on their own based on methods their instructors show them. Finding multiple methods for solving problems is usually not encouraged.
Contextualization	Math learning is centered around realistic problems or activities.	Math questions are generally presented as context-less equations or formulas and are not connected with real-life applications.
Reading and writing	Problems are generally a narrative, and students have reading as part of homework assignments. Students also write out responses to problems, either to explain their answers or provide an opinion. Some classes, particularly those with students with low literacy skills in English, faced challenges with the DCMP's reading and writing components.	Very little reading and writing observed. If narrative text is present, instructors read it aloud to students. Some instructors encourage notetaking.
Technology	Students use calculators in class and MyMathLab for homework. Rarely, some classes may also use other tools such as Excel, YouTube, or Calaytics.	Students use calculators in class and MyMathLab for homework.

SOURCE: Data collected from CAPR's field research at the four colleges participating in the study.

includes class activities that provide opportunities for students to engage in discussions about math (for instance, in small groups, class discussions, and interactive lectures). Active learning was prominent in most Foundations, Statistical Reasoning, and Quantitative Reasoning classes; about two-thirds of the classes observed devoted more than half of class time to having students work in small groups to solve problems. Generally, DCMP instructors provided a brief introduction to the lesson, and then presented multistep problems on the board successively throughout the class, with students breaking into small groups to solve each new problem as it was presented. Instructors spent little class time lecturing, and when they did, it was limited to short lectures to introduce a concept or problem. Instructors also encouraged students to work collaboratively throughout the class period. Box 3.2 provides an example of how these practices looked in a Foundations class.

Box 3.2

A Look Inside a DCMP Foundations Class

At the start of class, the Foundations instructor briefly explains what students did in the previous class — using proportion to examine blood alcohol levels — and notes they will be using proportions again in this lesson. He poses a few questions as review — "What is a proportion" and "What do we do to solve [a proportion] if we have an unknown value?" Students then discuss the answers to these questions before reviewing how to multiply and divide fractions.

On the whiteboard, the instructor projects the objectives for the lesson and the first math question:

> The Heart Health Association is holding a 5K Fun Run/Walk. An artist has donated her time to enlarge the logo for the advertising banners and the T-shirts that will be given to each runner.
>
> Many professionals such as graphic artists, architects, and engineers work with objects that are enlarged or shrunk. In this lesson, you will explore the mathematics behind these changes in size.
>
> The artist wants to set up a spreadsheet to calculate the dimensions of the graphics for the T-shirt and banner so that she can reuse it for future projects. She is not sure how to write the formulas correctly and tries different options. Which of three options creates a proportional relationship? (Hint: If a relationship is proportional, the image is not distorted.)

	A	B	C	D	E	F	G	H	I
1		Height (inches)	Width (inches)		Height (inches)	Width (inches)		Height (inches)	Width (inches)
2	Original	1.67	2.49		1.67	2.49		1.67	2.49
3	T-shirt	1.67	9.96		6.68	8.72		8.35	12.45
4	Banners	1.67	24.9		25.05	32.37		23.28	34.86

(continued)

Box 3.2 (continued)

The instructor then asks students to talk with one another (students are already sitting in small groups that the instructor had designated before class began) to work out which options create a proportional relationship, and students talk as they work. After a few minutes of students working together, the instructor explains that students should test out the different numbers presented to see which proportions are correct. The instructor walks around the class, engaging with each group to discuss its process for figuring out the correct proportion. When students ask questions or the instructor notices they may be on the wrong track, he explains that they need to test out other proportions. After 10 minutes, the instructor then returns to the front of the classroom, and the students discuss their answers with him and their classmates.

The instructor displays the next part of the problem:

> Use the correct option from Question 1. Write the spreadsheet formulas that are used to calculate the width for each version (T-shirt and banner). Use the column and row labels shown for the cell references. Round the ratio to the nearest hundredth.

The instructor then asks, "What mathematical operations did she use to get numbers in different cells?" then says, "I want to see if there is any relationship between them."

He asks students to work with their partners to figure out what mathematical operations were used to get the numbers in different cells and what relationship there is between them. After several minutes, he provides a hint that they are only looking at the width values ("How can you tell if one operation was used?"). After about five minutes, he prompts students with questions such as, "What do you think it is?" and "Is she adding to get these numbers?" as they work to solve the problem. Students reply that they believe the artist in the example is using multiplication.

The instructor asks, "How can we test to see what she multiplied by?" Students reply that he should do the opposite (meaning, divide). Instructor writes on the board $\frac{12.45}{2.49} = 5$ and $\frac{34.86}{2.49} = 14$, and asks "Did we get the same number on both of them?" Individual students volunteer to explain how they were able to solve for proportion. The instructor asks if there is a formula they can use to solve for proportions. Students call out that you use height/width to get the original ratio, and then the instructor writes the formula out on board.

NOTE: These data are based on a classroom observation the CAPR research team conducted.

This observation is not necessarily representative of all DCMP curricular classes; it was selected to highlight key differences between the DCMP's recommended pedagogical practices and traditional instructional approaches.

Many students commented on these practices in focus groups, noting that they frequently worked with other students in their classes. In one class, students reported that they always worked in small groups — their instructor refused to allow students to work independently. As one student put it:

> [We] start off with groups, then do our questions. Once each group has answers, then students present on the board… [Our instructor] gives us the opportunity to

> figure it out, then she helps explain. She's always walking around, helping. It's a lot better than working individually — helps [us] to keep focused… [There's] never a time that you see one student staring at the wall.

Many Foundations students appreciated this approach. As one student said, "You learn better this way because you're in a group, so there's a lot of support. If you're by yourself, then you don't know how to do it. Even though the class is two hours long, your brain is like go-go-go-go. It wakes you up for the day."

While instructors implemented active learning in most classes, implementation of active learning was more mixed in about a third of the classes observed. These classes generally incorporated more group work and interaction between instructors and students than standard developmental classes; however, these instructors still tended to rely on lecture to deliver course content. These instructors typically read instructions aloud for each activity and then demonstrated how to complete certain problems on the board, rather than first having students attempt to complete the activity in groups. These challenges with active learning occurred more frequently in very small classes (that is, fewer than five students), in classes with large proportions of English-language learners, and in classes where teachers were concerned about having adequate time to cover all the material.

Despite challenges in some DCMP classes, most of the 28 DCMP classes that were examined differed markedly from standard developmental math and college algebra classes. The standard classes were almost universally lecture-based. In these classes, an instructor worked through problems on the board or on a document camera, while students silently took notes. Occasionally, teachers posed one or two questions to the class and students volunteered answers, but this was infrequent. In most cases, teachers demonstrated how to solve the problems, rather than students discovering on their own. Four of the 24 standard developmental math and college algebra classes that were observed allowed at least some opportunity for students to work together, although only two of these classes had students working in groups for most of the class period. Box 3.3 presents an example of a standard developmental math class with a strong lecture focus.

Box 3.3

A Look Inside a Beginning Algebra Class

A Beginning Algebra instructor begins class by explaining to students how to combine algebraic terms and how to combine unlike terms, using a document camera to display her notes to the class. She starts by writing examples of like algebraic terms such as $\frac{3x^2}{4x^2}$ and $\frac{3ab}{5ab}$. She also writes equations with unlike terms, such as $\frac{x}{y}$, $\frac{3x}{4x^2}$, and $\frac{4m}{-6m^3}$. The instructor explains a "coefficient" of a term; in her words, it's a "numerical or number part of a term." The instructor then moves to looking at variables: "If you have $3x^2$, the coefficient is 3." The instructor writes out the term "variables" with coefficient and examples, and then removes them from the document camera after two minutes.

(continued)

Box 3.3 (continued)

A student asks, "What if we have 3^2? What's the coefficient?" The instructor responds, "We would still use our order of operation process."

The instructor then moves to looking at polynomial expressions in x and writes on the display:

Sum of terms, in the form of ax^n, a → real #, n is a whole #

The instructor explains that this "Just means a collection of terms, separated by + or – signs." As the instructor lectures, students copy everything the instructor writes down.

Next, the instructor spends about seven minutes lecturing about some common polynomials. She writes "Three common polynomials," and then the term *monomial*. She asks the class what "mono" means, and the students respond "one." The instructor then explains, while writing out key terms, that monomials are polynomials with one term, such as 3, x^2, $3ab$, and $-2x^2$. She tells students that these are still one term, and "you know that you have two terms if you have a + or – sign." The instructor asks students to give an example of a polynomial with two terms; two students respond.

Finally, the instructor explains a "trinomial," or a polynomial with three terms (for example, $3x^2 + 5x - 10\ or\ 3m - 10n + 4y$). The instructor asks students to look at their workbooks and determine what kind of terms the different problems are. The class spends about five minutes calling out problems, and what type of term they are.

The projector stops working, so the instructor moves to writing on the whiteboard. She writes out "degree of a term: sum of the exponents on the variables." She then writes out two problems:

$3x^4$ → degree 4

$2y^{15}$ → degree 15

The instructor asks if everyone has the notes written down. She then explains as she writes that the degree is the greatest exponent on any one non-zero term, and then presents two examples:

$3x^4 + 5x^2 - 8$ → degree 4

$5x^6 + 10x^4 - 3x$ → degree 6

The instructor then moves on and continues lecturing for 10 minutes — she prompts students with "Variables are what?" and then "What doesn't change?" Students reply with numbers, then the instructor explains what a constant is, and that the degree of a constant is 0.

After about five more minutes of writing out terms on the whiteboard and explaining to students how they can add exponents to find the degree, she asks if anyone has any questions. No students ask questions. The instructor then moves to the next unit: adding and subtracting polynomials.

NOTE: These data are based on a classroom observation that the CAPR research team conducted. This observation is not necessarily representative of all standard developmental classes at colleges participating in the study; it highlights key differences between a traditional approach to math instruction and the Dana Center Math Pathways' recommended pedagogical practices.

Survey results from program and standard group students during their first semester of coursework underscore these findings, with strong statistically significant differences between program and standard groups on these measures. As shown in Table 3.2, around 70 percent of students in the program group reported that they often discussed and shared strategies with other students, worked with other students on problems, and worked in small groups. Over half also reported that they explained their work to other students. In contrast, less than 20 percent of students in the standard group said they worked with other students, worked in small groups, and explained their work to other students. Standard group students were also significantly more likely to work on problems on their own (59 percent compared with 32 percent of program group students). These differences are all statistically significant at the 1 percent level.

Constructive Perseverance

As a pedagogical practice, constructive perseverance aims to build students' metacognitive skills, which help them to monitor their own learning and persist through challenging tasks. When observing classes, CAPR researchers looked to see if students were given time to work through problems on their own and with their classmates, potentially with hints and suggestions from their instructors, rather than be given answers directly by their teacher. Constructive perseverance was implemented with relatively strong fidelity across nearly all the DCMP developmental and college-level courses. Most DCMP instructors who were observed implemented constructive perseverance techniques, such as allowing students to struggle with material and assigning preview lessons that contained basic skills tasks that had not yet been covered in class. In the classrooms, instructors pushed students to consider other options when they posed questions about the material, replied with further questions rather than providing solutions directly, and encouraged other students to explain the solutions to their peers.

Students also commented on instructors' use of constructive perseverance techniques and generally were positive about this approach. In most cases, students reported that this method helped them feel more confident in their math skills and competent with math in general. For instance, one student who liked the approach explained that:

> If you don't get it, [the teacher tells us to] discuss with your partner — "Ask three before me." — then ask another group, then ask the teacher. I like how she does that because even if you ask a question and you're expecting an answer, she just asks, "What do you think?" She makes you work for it. She challenges you to figure it out. It's like motivational interviewing.

While a majority of students felt positive about this approach, a few students expressed frustrations with these course techniques. Most often these students noted that they did not understand how preview assignments related to the next day's lessons.

Although most DCMP instructors successfully implemented attributes of constructive perseverance in their teaching, DCMP faculty in four of the observed classes faced some challenges. In these cases, instructors tended to provide solutions for the students or step in quickly if they noticed that the students were struggling. Some instructors also mentioned having a

Table 3.2

Presence of Active Learning, Problem Solving, and Constructive Perseverance in Developmental Math Classes, Student Survey Responses

Response (%)	Program Group	Standard Group	Difference	P-Value
Active learning				
Always or often during class:				
Students worked on problems on their own	31.9	58.9	-27.0***	0.000
Student worked with other students on problems	73.2	17.6	55.6***	0.000
Students worked in small groups	74.7	15.8	58.9***	0.000
Student explained work to other students	56.2	13.7	42.5***	0.000
Students discussed and shared strategies	69.2	31.9	37.4***	0.000
Problem solving and constructive perseverance				
Always or often during class:				
Instructor encouraged students to find own way	64.4	42.4	22.0***	0.000
Instructor showed class multiple ways to solve problems	66.7	53.5	13.3***	0.000
Homework prepared students for next class	65.8	54.7	11.2***	0.000
Homework tested students' understanding	66.6	51.9	14.8***	0.000
Agreed or strongly agreed with the following statements about math class:				
You learned how to struggle through problems	65.4	54.5	10.9***	0.001
You tried to work through problems even if instructor hadn't yet taught how	58.1	52.4	5.8*	0.076
Thought the following statements were always or mostly true about math class enrolled in:				
Instructor did not let people give up	68.3	55.9	12.3***	0.000
Instructor expected you to solve problems on your own	40.9	27.0	14.0***	0.000
Sample size (total = 1,411)	856	555		

SOURCE: CAPR calculations based on a survey of study participants at Brookhaven, Eastfield, El Paso, and Trinity Valley Community Colleges.

NOTES: Rounding may cause slight discrepancies in sums and differences.

Statistical significance levels are indicated as: *** = 1 percent; ** = 5 percent; * = 10 percent.

This survey was sent to all cohorts near the end of their first semester in the study except for the fall 2015 cohort. Students in this cohort, to whom the survey was sent during their second semester, were asked to think about their math class from the previous semester when responding to questions.

The survey was sent to 1,411 students. The overall survey response rate was 71 (71 percent in the program group and 70 percent in the standard group). No more than 4 percent of survey respondents failed to respond to any specific item.

Students not taking a math class were not asked to respond to these survey items. Researchers used imputed values of 0 for these students.

difficult time getting their students to stay engaged with the material, noting that some students became annoyed with not having their questions answered directly. As one instructor explained, "struggling was not always productive," and she feared that DCMP students would leave her class with less confidence in their ability to succeed in math than standard developmental math students. Most of these challenges were observed in the first year of implementation, and the quality and consistency of instructors' use of constructive perseverance techniques improved in the second year.

While instructors in most DCMP classes regularly implemented constructive perseverance techniques, this was much less consistent in standard developmental math and college algebra classes. Across almost all class observations of standard developmental and college-level algebra courses, instructors gave students solutions to problems upon request or as part of the lecture. Some of this was likely the result of the lecture-based nature of the courses, where students had few opportunities to solve problems on their own. Even when students were encouraged to solve problems independently, the instructor was still likely to provide students with solutions when they asked for help.

Student survey responses echoed these observations (as shown in Table 3.2). Nearly 64 percent of program group students reported that their instructor always or often expected them to find their own way, in comparison with 42 percent of standard group students. The survey also found differences in students' reported attempts to struggle through problems (65 percent of program group students, compared with 55 percent of standard group students) and students' perspectives on whether their instructors would not let them give up (68 percent of program group students compared with 56 percent of standard group students). All of these differences are statistically significant at the 1 percent level.

Problem Solving

As Chapter 2 notes, another goal of DCMP's redesigned curricula was to support the students' active participation in problem solving, including finding or developing multiple strategies to solve problems. Problem solving was another strongly implemented standard in DCMP courses, both at the developmental and college level. When teaching DCMP classes, instructors generally asked students to solve multistep problems with a partner or in small groups, with limited input from their instructor. Once each group had reached a stopping point, the instructors typically gave students an opportunity to share and discuss their solutions with the rest of the class. In some DCMP classes, particularly Statistical Reasoning, this also became an opportunity to share alternative methods for solving problems.

Many students commented on these practices in focus groups and noted that seeing multiple methods for solving problems helped their learning. As one student said, "[Our Foundations instructor] always shows us at least three ways. And she gives us the choice — like, you pick whichever way you feel is the easiest. She'll pretty much show us every single way to solve a problem." Instructors also frequently commented on the challenging nature of the DCMP problems. As one Foundations instructor said, "I would describe the problems they work on as thought-provoking. Frustrating [laughs]. I think they require a lot of thought. I know the goal is to get students [engaged in] problem solving and critical thinking, and I think it does that very well."

In contrast, standard developmental math and college algebra classes offered very limited opportunities for students to solve problems together. Instead, instructors typically presented a solution method and solved example problems; students took notes or worked through problems alongside their instructor. In some cases, students worked on their own to solve an equation or other mathematical procedure. However, instructors generally requested that students follow the same method that they used. It was rare for instructors in these courses to present multiple methods for solving problems, and in one class, the instructor penalized students who attempted to solve problems in ways other than what they were taught.

Student survey responses reveal that instructors provided multiple solution methods in both DCMP and standard developmental classes, although the practice was more prevalent in DCMP classes. (See Table 3.2.) Sixty-seven percent of program group students said their instructors always or often showed them multiple ways to solve a problem, compared with 54 percent of standard group students. More program group students than standard group students reported that their instructors expected them to solve problems on their own (41 percent compared with 27 percent). Differences between students' experiences were significant at the 1 percent level.

Contextualization

Contextualization is a pedagogical method that integrates real-life situations, material from relevant academic disciplines, or the use of real data sets into the math curriculum. All DCMP developmental and college-level courses that the researchers observed had highly contextualized math instruction. Instructors in all the observed DCMP courses centered math learning within realistic problems or activities, often through multistep word problems. Box 3.2 and Box 2.1 (from Chapter 2) are examples of this type of contextualization, in which students are asked to analyze or apply a mathematical concept in the context of a high-interest subject, such as resizing a college logo to fit on a banner or a T-shirt (see Box 3.2) or measuring body mass index. Other lessons use charts and graphs to analyze and compare various attributes related to vehicles, such as braking distance or miles per gallon. As one instructor put it, "Everything is given the contextualized way. Mathematics isn't an abstract thing. It drives home the fact that mathematics is important. It helps them think more critically." Students in virtually all the focus groups commented on the contextualization, noting how it engaged them and helped them see how they could use math in their everyday lives. As one student said, "I find myself calculating things I used to not do, like the cost and ounces in a shampoo bottle to see how to save money."

While all DCMP courses had some level of contextualization, almost all standard developmental math and college algebra classes that were observed presented math problems as equations or formulas. Generally, these problems were presented with no explanation of how they could be used in a real-life situation. Additionally, the problems generally called for straight computation rather than comparisons of different answers. Of the 24 classes of standard developmental math and college algebra the researchers examined, only two instances of contextualization were observed. In both instances, contextualization was not part of students' curriculum (for instance, part of their textbook or homework), and the examples the instructor presented appeared to be less immediately applicable to students' lives or majors. For example, in one class, the instructor used real-life situations to demonstrate concepts (for example, using population changes in different countries to explain exponential growth), but math questions were still usually presented as stand-alone equations.

Survey results also underscore these observations. Seventy percent of program group students reported that they were often or always taught using real-life problems in comparison with 38 percent of standard group students. (See Table 3.3.) Similarly, 58 percent of DCMP students reported that the problems presented in class were often couched in real-life contexts, while only 23 percent of standard group students reported experiencing this regularly. These differences are statistically significant at the 1 percent level.

Table 3.3

Presence of Contextualization, Reading and Writing, and Technology in Developmental Math Classes, Student Survey Responses

Response (%)	Program Group	Standard Group	Difference	P-Value
Always or often during class:				
Problems used information from real life	57.5	22.5	34.9***	0.000
Students had to read	63.8	35.1	28.7***	0.000
Students were asked to write out reasoning	59.1	20.2	38.9***	0.000
Students were asked to explain work orally using math terminology	56.2	28.2	28.0***	0.000
Students used a computer in class or at home	61.4	52.2	9.2***	0.005
Agreed or strongly agreed with the following statements about math class enrolled in:				
Class was taught using real-life problems	70.0	37.9	32.2***	0.000
Class taught you to think more about what you're learning	76.3	59.2	17.1***	0.000
Sample size (total = 1,411)	856	555		

SOURCE: CAPR calculations based on a survey of study participants at Brookhaven, Eastfield, El Paso, and Trinity Valley Community Colleges.

NOTES: Rounding may cause slight discrepancies in sums and differences.
Statistical significance levels are indicated as: *** = 1 percent; ** = 5 percent; * = 10 percent.
This survey was sent to all cohorts near the end of their first semester in the study, except the fall 2015 cohort. This cohort, to whom the survey was sent during their second semester, was asked to think about their math class from the previous semester when responding to questions.
The survey went to 1,411 students. The overall survey response rate was 71 (71 percent in the program group and 70 percent in the standard group). No more than 4 percent of survey respondents failed to respond to any specific item.
Students not taking a math class were not asked to respond to these survey items. Researchers used imputed values of 0 for these students.

Reading and Writing

The DCMP curricula also emphasize the development of students' ability to read and write about their math problem solving and solutions, and a large proportion of DCMP instructors were faithful to these goals: Nearly 75 percent of the instructors that the researchers observed implemented the practices in the classroom.

Most DCMP classes incorporated reading and writing extensively, meaning that instructors typically presented problems as multistep narratives, and students regularly wrote their answers to problems in complete, contextualized sentences. For example, in a lesson focused on civic life, the instructor presented a graph illustrating how the U.S. national debt had changed over time.[5] Students then had to write their responses as they considered the following statement: " 'The 2010 national debt is way out of hand and has never been higher.' Do you agree or disagree?" This type of analytical question, which required students to write a narrative response, was common among courses in the DCMP curricula and in the observed classes. Reading and writing were particularly pronounced in the college-level DCMP courses — in nearly all Statistical Reasoning and Quantitative Reasoning classes observed, students read word problems in class and were often required to provide written explanations for their answers.

Some Foundations instructors reported some challenges with implementing reading and writing, and researchers observed five (out of the 19) Foundations instructors who struggled with implementing writing in their classes. The problems generally related to some students' low English literacy skills. They said that these students struggled to read and write about the material, and that the implementation of reading and writing was particularly challenging in classes with a substantial population of English learners. In these classes, instructors spent more time than instructors in other classes reading and explaining lessons or problems.

In contrast, standard developmental math and college algebra classes tended to integrate little reading and writing. Less than half of the observed developmental and college algebra classes required any kind of reading; instructors presented most problems as de-contextualized formulas or equations. Additionally, instructors who introduced a narrative tended to read it aloud. Students occasionally read when they were given word problems or materials created by the instructor, such as written definitions for key terms or writing on PowerPoint slides.

Observers saw few instances of students writing in the standard developmental math and college algebra classes. Most students who were writing were taking notes. One instructor required students to summarize their understanding of lessons in writing, which the instructor checked prior to an exam. However, this was the only example noted where students were asked to summarize their learning in narrative form. When asked about writing, the instructors had mixed reactions — some did not believe that writing belonged in a college math class while others wished they could do more but faced challenges integrating writing into class activities.

Student survey responses also demonstrate these differences. (See Table 3.3.) There is a 29 percentage point difference in student reports of the frequency of reading in program and standard group students' classes (64 percent of program group students versus 35 percent of standard group students) and a 39 percentage point difference in the frequency of writing out their reasoning (59 percent versus 20 percent). The students' self-reported differences in the frequency of reading and writing in math classes are statistically significant at the 1 percent level.

---

[5]Foundations of Mathematical Reasoning curriculum (2014), Lesson 4, Part D (page 164).

Technology

The Dana Center highlighted the use of technology as another important curricular standard in DCMP courses. Specifically, the DCMP curricular standards encourage instructors to use technology to facilitate and support math instruction. Notably, the use of technology was one of the few areas that DCMP classes had in common with standard developmental math classes. Researchers frequently observed standard developmental students and DCMP students in Foundations, Statistical Reasoning, and Quantitative Reasoning classes using calculators. Students in nearly half of all the classes also reported regularly using MyMathLab for their homework. However, DCMP courses were slightly more likely than standard developmental classes to use other types of technology for instruction, such as Excel or YouTube, although these instances were rare even in DCMP courses. DCMP instructors were also slightly more likely to allow students to use smart phones in class, either as calculators or to look up information about the lessons. In contrast, instructors explicitly banned cell phones in many standard developmental math classes. This difference may be related to the DCMP curriculum's emphasis on the real-world applicability of math.

Researchers found statistically significant differences between survey responses from the standard group students and the program group on their use of computers. As Table 3.3 shows, 61 percent of Foundations students reported regularly using a computer in class or at home, compared with 52 percent of standard group students, a difference that is statistically significant at the 1 percent level.

Non-DCMP Statistics and Quantitative Reasoning Courses

DCMP college-level courses were very similar to Foundations courses in their structure and recommended pedagogy. However, most students in the program group who enrolled in a college-level math course within the three semesters following enrollment into the study took their colleges' standard offerings of statistics and quantitative reasoning courses. (See Appendix Table A.1.) As a result, CAPR researchers also examined a selection of these courses to consider how they were taught, and how students' experiences with these courses may have differed from those taking DCMP courses or college algebra. This section briefly describes the instruction in these classes; however, the analyses should be interpreted with caution given that researchers observed relatively few of these courses (15 total), and the colleges offered many more sections of these courses than researchers were able to observe. (See Table 3.1.)

Statistics

Based on data from nine standard statistics classes, standard statistics classes had some similarities to classes taught using the DCMP statistics curriculum. Most had some level of contextualization, presenting classroom or homework problems using real-life situations. However, many of these classes also presented formulas and equations with limited references to how they might be useful in everyday life. Standard statistics classes also tended to incorporate some reading and writing; students reported that word problems were regularly assigned for homework, and in some classes, instructors assigned reading from a textbook. Finally, many also used technology, including calculators and software programs such as MyMathLab or StatCrunch.

However, the standard statistics classes that were observed tended to be lecture-based rather than incorporating active learning techniques. There were some observed instances of individual or small group practice, but in only one observed class did students regularly engage in group work and actively solve math problems. There was limited constructive perseverance in standard statistics classes. Instructors encouraged students to initially grapple with problems, but they generally provided them with the answers, particularly if students were disengaged in class. Notably, instructors in these courses reported that they reserved class time for students to try multiple problem-solving methods.

Quantitative Reasoning

Standard quantitative reasoning courses resembled DCMP courses in several ways, based on data from six classes. Students were observed solving problems together; instructors in those classes encouraged group problem-solving and used interactive lecture techniques that fostered discussion among students. Instructors also generally used prompts and guidance to help students find their own solutions, although they tended to eventually provide answers. These classes frequently used contextualized math problems relevant to students' degree programs. However, the standard quantitative reasoning courses incorporated fewer opportunities for reading and writing than DCMP courses. While some of these classes integrated word problems into their lessons, the researchers saw few other examples of in-class reading and writing, nor did the instructors mention these techniques.

Students' Perspectives on Their Math Classes, and Math Classes' Influence on Students' Attitudes Toward Math

Overall, students in all the classes were generally positive about their courses and their teachers. Students in DCMP classes, however, often said that their learning experiences made them more confident in their ability to succeed in math and changed the way that they felt about the subject overall. As one student explained, "I used to hate math. [...] It's more of a 'like' now."

Students in other courses were also positive about their math classes and instructors. For instance, most standard developmental math and college algebra students said that they generally appreciated their teachers' ability to "break down questions," which improved their confidence in math. Many students in quantitative reasoning and statistics courses discussed their appreciation of the real-world applications and the practical applications these courses afforded them. As one student in a standard quantitative reasoning course noted, "It's like real-life stuff. It's real-life problems and applications. I don't care about finding *y* unless I'm finding a value on a five-year loan."

Despite this, the student survey presents important differences in program and standard group students' engagement in their math classes and attitudes toward math. For instance, significantly more program group students reported paying attention in their math class and using the math they learned in daily activities. More program group students also found the math that they were learning to be interesting. (See Table 3.4.) Additionally, more program group students said their math class had increased their confidence and interest in math. Similarly, when asked about their attitudes toward math more generally (and not as an effect of their math class), significantly more program group students noted an understanding of how math would be used in their future and their everyday life.

Table 3.4

Students' Perspectives on Their Developmental Math Class, and Impacts on Their Attitudes Toward Math

Response (%)	Program Group	Standard Group	Difference	P-Value
Perspectives on developmental math class[a]				
Difficulty of math class enrolled in:				
Easy or very easy	25.8	22.0	3.8	0.178
About right	48.1	38.3	9.7***	0.003
Difficult or very difficult	13.5	22.0	-8.5***	0.000
Thought the following statements were always or mostly true about math class enrolled in:				
You felt bored during class	12.0	14.4	-2.4	0.271
You paid attention during class	77.7	69.9	7.8***	0.006
You went to class unprepared	4.6	3.7	0.9	0.500
You worked very hard on your math	71.0	66.0	5.0*	0.098
What you learned was interesting	51.1	36.9	14.2***	0.000
You use the math you learned for daily activities	45.8	23.1	22.7***	0.000
Class made you more confident in math ability	54.3	46.8	7.5**	0.023
Class increased your interest in math	36.3	28.2	8.1***	0.009
Impacts on attitudes toward math[b]				
Agree or strongly agree with the following statements				
Confidence in and enjoyment of math:				
Intelligence is born and can't be changed	9.2	8.8	0.4	0.814
The more you work at math the better you'll be	59.0	62.2	-3.1	0.334
You are confident with math	38.2	38.1	0.1	0.984
You know you can handle difficulties in math	41.5	39.2	2.4	0.462
Learning math is enjoyable	38.2	38.6	-0.4	0.901
Utility of math				
You understand how math will be needed in your future	68.7	61.4	7.3**	0.020
You use the math you learned in everyday life	53.9	37.7	16.2***	0.000
Sample size (total = 1,411)	856	555		

(continued)

Table 3.4 (continued)

SOURCE: CAPR calculations based on a survey of study participants at Brookhaven, Eastfield, El Paso, and Trinity Valley Community Colleges.

NOTES: Rounding may cause slight discrepancies in sums and differences.
Statistical significance levels are indicated as: *** = 1 percent; ** = 5 percent; * = 10 percent.
This survey was sent to all cohorts near the end of their first semester in the study, except the fall 2015 cohort. The students in this cohort, to whom the survey was sent during their second semester, were asked to think about its math class from the previous semester when responding to questions.
The survey went to 1,411 students. The overall survey response rate was 71 (71 percent in the program group and 70 percent in the standard group). No more than 4 percent of survey respondents failed to respond to any specific item.
[a]Students not taking a math class were not asked to respond to these survey items. Researchers used imputed values of 0 for these students.
[b]All students were asked survey questions about their attitudes toward math, regardless of whether they were currently taking a math class.

While these findings are promising, no significant differences were seen in program group students' overall confidence in math, their enjoyment of math learning, or overall confidence in their ability to handle difficulties in math problems compared with those in the standard group. Less than half of the students who responded to the survey agreed or strongly agreed with these statements, regardless of their study group.

Summary

Overall, developmental and college-level courses taught using the DCMP curricula had relatively strong fidelity to the principles outlined in the Dana Center's curricular design standards. Though some challenges existed in a few courses with implementing active learning and reading, nearly all the courses that researchers examined in their field visits had high levels of these two practices as well as contextualization, problem solving, writing, constructive perseverance, and use of technology. Instruction in classes using the DCMP curricula differed sharply from instruction in standard developmental math classes and college algebra, which, outside of using technology, integrated few of these practices. Colleges' standard college-level statistics and quantitative reasoning courses tended to have more in common with the DCMP curricular courses, with more examples of contextualization, reading, and writing.

Students in both the DCMP and standard study groups expressed positive views of their courses and their instructors in focus groups, although their survey responses showed strong statistically significant differences in how they learned math and in their understanding of how math applied to their everyday life. Despite this, students' overall confidence and enjoyment of math was similar: Fewer than half of students in both groups reported that they enjoyed learning math or felt confident in their abilities to handle math difficulties.

Chapter 4

Impact of the DCMP on Student Outcomes

This chapter discusses the impact of the Dana Center Mathematics Pathways (DCMP) on developmental students' educational outcomes during their first few semesters after entering the study. As Chapter 1 notes, Texas community colleges identify students as being in need of developmental courses based on their test scores on the Texas Success Initiative Assessment, ACT, or SAT. Students who test below a state-mandated cutoff score are required to take one or more developmental courses.[1] This study examines the effects of the DCMP on students who were required to take one or two developmental math courses and who are planning on majoring in fields that would be eligible for the DCMP's statistics or quantitative reasoning math pathways. The four Texas community colleges in the study randomly assigned students to a program group, making them eligible to participate in the DCMP, or to a standard group that received the colleges' traditional developmental and college-level math courses. The program group students were eligible to take the DCMP's accelerated and revised developmental math course (Foundations of Mathematical Reasoning) followed by a college-level statistics or quantitative reasoning course. Students in the standard group could enroll in the colleges' standard math curriculum, which includes one or two developmental math courses (as determined by their test scores) followed by a college-level math course, usually college algebra.

The theory behind the DCMP model is that the accelerated and revised Foundations of Mathematical Reasoning course, paired with college-level math that is aligned with students' career interests, will improve students' academic performance. As Chapter 2 explains, the Foundations course differs from the standard developmental math course sequence in three fundamental ways. First, it replaces an exclusive focus on algebra with an emphasis on the development of students' numeracy, statistics, and algebraic reasoning skills. Second, the pedagogy is a more contextualized and student-centered learning approach than that of the standard course. Finally, the accelerated course sequence allows students who traditionally would require two semesters of developmental math to complete their requirements in one semester. The DCMP model's aim is to help students successfully complete their developmental math requirements and enroll in and pass their first college-level math class in less time, ideally within the first year of college. The model posits that these early academic gains will impel students to enroll in and pass additional courses more quickly, leading to higher credit accumulation. In turn, the model suggests that higher credit accumulation leads to greater overall academic progress, and ultimately to higher rates of receipt of certificates and associate's degrees or earlier transfer to four-year institutions to pursue baccalaureate degrees.

[1]Texas Higher Education Coordinating Board (n.d.).

This chapter looks at the impact of the DCMP program on developmental students' progress in math and their overall academic progress.[2] It also takes an early look at the impact of the program on students' college completion and transfer. Finally, the chapter explores the DCMP's different impacts across various groups of students.

Key findings from this chapter include:

- Students in the program group were significantly more likely to pass a developmental math course and become college-ready in math by the end of their first semester of college than their standard group peers. Positive impacts on these measures persisted during students' second and third semesters.
- Program group students were also 11 percentage points more likely to pass a college-level math course during their second semester, and almost 7 percentage points more likely to have ever passed a college-level math class by the end of their third semester. On average, they earned 0.2 more college-level math credits during the first three semesters than students assigned to the standard math sequence.
- Program group students also earned similar numbers of non-math credits as the standard group, suggesting that the program group students did not neglect other courses in order to earn more math credits. Overall credit accumulation was similar for program and standard group students.
- Exploratory findings on college completion show a small impact of the DCMP on students' earning a certificate by the end of two years of college. No impact was found on the combined measure of earning a certificate or degree or transferring to a four-year college during that period. Only about 14 percent of program group students had earned a degree or transferred to a four-year college by the end of the second year, compared with 13 percent of standard group students. It is likely too early to determine program impact on these measures.
- Exploratory analyses suggest that the DCMP impacts are concentrated in the group of students who were lower performing (scoring two or three levels below college-ready on the math placement exam) prior to the start of college. The program also appears to be more effective for students planning to attend college part time compared with full-time students.
- There were few differences in the impacts of the program for subgroups of students based on their race and ethnicity or their gender.

[2]The DCMP model examined in this study includes the use of the DCMP curricula, which are included in all developmental and some college-level courses; however, the use of these curricula is not required for implementing the Dana Center's broader DCMP model based around the four principles. See Chapter 2 for more details.

Impact Study Design

Four cohorts, consisting of students who enrolled in the study over four semesters (fall 2015, spring 2016, fall 2016, and spring 2017), participated in the study. With a total of 1,411 students, 856 were assigned to the DCMP and 555 were assigned to the colleges' standard developmental math sequence.[3] This chapter includes impact findings for all study participants through their first three semesters of college. To capture the longer-term outcomes of certificate and degree completion and transfer to four-year colleges, researchers analyzed student outcomes for the first three cohorts after four semesters (or two years) of college.[4]

The study used a generalized linear model to estimate the effect of the opportunity to participate in the DCMP. The impact analysis estimates show the causal effects of the opportunity to participate in the DCMP program, focusing on the full sample of students who were randomly assigned. See Chapter 3 for a description of how to interpret the impact tables. All impacts in this chapter are statistically significant unless otherwise noted. Data used in the analyses for this chapter include study participants' college transcript records and National Student Clearinghouse data.[5]

This chapter addresses these research questions:

1. Do DCMP students have better academic outcomes than students in the standard developmental math sequence?

2. Is the DCMP more effective for certain groups of students?

Outcome Measures

To answer the first question, an array of outcome variables connected to students' progress in math, overall academic progress, and college completion or transfer will be discussed. Researchers specified five key outcomes as confirmatory prior to conducting any analyses because of their direct connection to the hypotheses being tested. For this study, these five outcomes are considered the main indicators of the DCMP's success.

---

[3]Baseline equivalency testing compared the program and standard groups on several measures, including race and ethnicity; age; gender; student's high school or college attainment prior to the study; and students' responses on several baseline survey items including whether they had ever failed a math class in high school or college, and their attitudes toward math. The overall test of equivalency showed that, on average, the two groups were similar prior to the program.

[4]All other outcome measures were also analyzed for this group, and impact findings were similar to the full sample.

[5]Some students never registered for classes at the colleges and/or were not found in the National Student Clearinghouse database. In both these cases, students without records are assumed to have not enrolled in college, and all outcomes are imputed as zero. In this way, attrition and differential attrition should not bias impact findings.

1. **Completed Developmental Math Sequence.** The first confirmatory outcome is the percentage of students who successfully completed the developmental math sequence. Developmental courses are remedial courses that do not generate any credits toward college graduation or certificate attainment. These courses prepare students who have tested below college level to take credit-bearing college courses. In a standard developmental math sequence, students take a number of developmental math courses depending on their math need. For instance, a student testing two levels below college-ready would generally be placed into a sequence of two semester-long developmental math courses (Beginning Algebra, followed by Intermediate Algebra). A student testing one level below college-ready would likely be placed into Intermediate Algebra and would only need to pass this one developmental course before entering college algebra.

   As Chapter 1 discusses, the vast majority (83 percent) of the students in the study scored two levels below college level on the placement exam; 1 percent of study participants placed three levels below; 13 percent placed one level below; and 3 percent placed at college level.[6] Thus, for most students in this study, the accelerated developmental math sequence offered an opportunity to take college-level math more quickly than in the standard developmental math sequence.

2. **Ever Passed a College-Level Math Class.** The second outcome is the percentage of students who have ever passed a college-level math class. While the accelerated format of the DCMP's revised developmental math course may allow a student to complete developmental math more quickly, it does not necessarily mean the student has gained the skills needed for college-level math. If the course is just easier for students but does not fully prepare them for future coursework, then the first college-level math class may become a stumbling block. Looking at students' success in passing college-level math captures a fundamental goal of the DCMP, which is helping more students enroll in and pass college-level math during their first year of college.

3. **Math Credits Earned.** The third outcome is students' progress in the math sequence as measured by the number of college math credits earned. As noted above, the changes in content and pedagogy are hypothesized to allow for better understanding and retention of math concepts, which should aid students in their course trajectory. In addition, the accelerated format should allow students to enter college-level courses more quickly, and therefore accumulate more college-level math credits.

4. **Total Credits Earned.** Overall academic progress as captured by total credits earned is the fourth key outcome. While the DCMP is less directly related to earning non-math credits, the program is hypothesized to have an impact on overall academic progress in two ways: First, if students are earning more math credits and doing so is

[6]Although the study was targeted to students needing one or two developmental courses, a small number of students who tested three levels below college-readiness and some who tested college-ready also entered the study, suggesting that some counselors included students outside the study target group.

not negatively affecting their credit accumulation in other subjects, they can expect to earn more credits overall. Second, since the student-centered approach to learning in Foundations is in part intended to support and build students' study strategies in general, the program could have an indirect impact on non-math credit accumulation.

5. **Received a Degree or Enrolled at a Four-Year College.** The ultimate goal of the DCMP is that more students successfully complete college either by earning a certificate or degree or by transferring to a four-year institution. Developmental education can be an obstacle for students in meeting these longer-term goals because it can lengthen the time students need to be in college. Moreover, challenges with developmental courses can discourage students from persevering in college.[7] The confirmatory outcome is the percentage of students who meet any of these goals, but the study also looks at certificate attainment, degree attainment, and transfer separately.

Beyond these five outcomes, other outcomes this chapter discusses are considered exploratory, which means they are analyzed to help explain the impacts on the main confirmatory outcomes and to help characterize the effects of the program on students' academic progress.

Subgroup Analyses

The study team conducted subgroup analyses to shed some light on who the DCMP may best support. In particular, they looked at the effectiveness of the program for students more likely to struggle in college. The study compares students who tested two to three levels below college level with students who tested zero or one level below, students who planned to attend college part time compared with students planning to attend full time, and students who didn't enter college directly after graduating high school compared with students who did go directly into college. The study also explored differential effects of the program depending on the students' race or ethnicity and gender. All subgroup analyses are exploratory; they are meant to support a better understanding of the impacts on the key outcome measures discussed above. These analyses may offer some insights worth further exploration in future research.

Impacts on College Registration

Table 4.1 displays the impacts of the DCMP program on students' registration at the community college and their enrollment and performance in their developmental math sequence during the students' first three semesters of college. While not confirmatory outcomes, the measures of whether students were registered at the college during each of the first three semesters reflect the students' ongoing persistence at that college. While the DCMP is not hypothesized to directly affect college persistence — a student's ongoing enrollment in college — the possibility of a

[7]See for instance, Bailey, Jeong, and Cho (2010); Bettinger and Long (2009).

Table 4.1

Impacts on College Registration and Developmental Math Class Enrollment and Pass Rates

Outcome (%)	Program Group	Standard Group	Difference (Impact)	P-Value
First semester				
Registered in first semester	89.4	87.7	1.7	0.327
Ever enrolled in developmental math class	80.2	72.5	7.7***	0.001
Ever passed developmental math class	49.8	40.5	9.4***	0.001
Ever passed developmental math, among enrolled	*62.1*	*55.8*		
Ever withdrew from developmental math class	6.5	6.6	-0.2	0.909
Completed developmental math sequence[a]	47.4	11.4	36.1***	0.000
Second semester				
Registered in second semester	65.9	65.5	0.4	0.879
Ever enrolled in developmental math class	84.8	78.6	6.2***	0.003
Ever passed developmental math class	56.7	47.8	8.9***	0.001
Ever passed developmental math, among enrolled	*66.9*	*60.9*		
Ever withdrew from developmental math class	8.3	11.1	-2.7*	0.084
Completed developmental math sequence[a]	53.6	28.5	25.1***	0.000
Third semester				
Registered in third semester	48.3	47.7	0.5	0.846
Ever enrolled in developmental math class	85.6	80.2	5.4***	0.007
Ever passed developmental math class	58.7	50.7	8.0***	0.003
Ever passed developmental math, among enrolled	*68.6*	*63.2*		
Ever withdrew from developmental math class	9.3	12.5	-3.2*	0.054
Completed developmental math sequence[a]	57.0	33.5	23.5***	0.000
Sample size (total = 1,411)	856	555		

SOURCES: CAPR calculations using transcript data provided by Dallas County Community College District, El Paso Community College, and Trinity Valley Community College.

NOTES: Rounding may cause slight discrepancies in sums and differences.

Estimates are adjusted to account for the various community college campuses students attended and the four different semesters during which students were randomly assigned.

Outcomes shown in italics are nonexperimental. Statistical significance tests are not conducted on nonexperimental outcomes.

Statistical significance levels are indicated as: *** = 1 percent; ** = 5 percent; * = 10 percent.

[a]Students are included in “Completed developmental math sequence” if they completed the highest-level developmental math class or enrolled in a college-level math class. It is possible under some circumstances for a student to enroll in college-level math without ever taking or passing a developmental math class (that is, students can retake the math entrance exam).

connection between more engaging courses and early successes in developmental math and college persistence is worth exploring.

Eighty-nine percent of program group students registered for classes during the first semester, but by their third semester only 48 percent of program group students registered for classes. This decrease in enrollment is common in other studies of developmental education reforms,[8]

[8]See for instance, Weissman et al. (2011); Weiss and Headlam (2018); Scrivener, Sommo, and Collado (2009); Weiss et al. (2011).

and is indicative of the substantial barriers to college completion these students face. During these first three semesters, there is no impact of the program on initial registration or persistence at the college. Students in the program are just as likely as those who participated in the standard developmental sequence to register for classes at the college during this period.[9]

Impacts on Developmental Math

During the first semester, program group students were almost 8 percentage points more likely to be enrolled in developmental math than their counterparts in the standard group. While the gap in enrollment of these two groups lessens slightly over the three semesters, by the end of their third semester, students assigned to the DCMP were still over 5 percentage points more likely to have ever enrolled in a developmental math course compared with the students assigned to the standard group. It is unclear why program group students were more likely to enroll in developmental math during the first semester. While each of the colleges managed enrollment into developmental classes in somewhat different ways, all four colleges worked to ensure the process was similar for program and standard group students, often with the assistance of coaching from CAPR researchers. While the research team feels confident that the process was comparable for both groups, there is a possibility that some advisors conducting random assignment and enrolling students may have had different messaging for the two groups, such as communicating excitement if they were in the program group.

The DCMP program also had a positive impact on whether students passed a developmental math course during the first three semesters. In the first semester, program group students were 9 percentage points more likely to pass developmental math than those assigned to the standard sequence, and not much changed by the third semester, where DCMP students were still 8 percentage points more likely to have passed at least one developmental math class.

As noted above, more program group students enrolled in developmental math than standard group students, and this could be a key factor in more students passing the course. The outcome, "Ever passed developmental math, among enrolled," shows the percentage of students enrolled in developmental math from each group that passed the class. While this is not a causal measure because some study students did not enroll in any developmental math course, it does show higher passing rates among DCMP students, suggesting that the higher enrollment is not the only reason for the higher pass rate. Students in the program group were also less likely to withdraw from a developmental math course than standard group students in the second and third semesters.

[9]The study team also looked at whether the DCMP had an impact on the percentage of students transferring to another college during the first three semesters. Approximately 4 percent of students transferred to another college in the first semester, approximately 9 percent had transferred to another college by the end of the second semester, and about 14 percent had transferred by the end of the third semester. The DCMP had no impact on students' choice to transfer during this period.

Because the program works directly to ensure that students pass through the developmental math sequence and into college-level math more quickly, the key confirmatory outcome in Table 4.1 is the percentage of students who completed the developmental math sequence.[10]

- **Program group students were much more likely than the standard group students to complete their developmental math sequence and become college-ready in math during the first three semesters of college.**

At the end of the first semester, program group students were 36 percentage points more likely to have completed the developmental math sequence than standard group students, allowing many more program group students to enter college-level math within their first year of college, a stated goal of the DCMP. The large impact on completing the developmental math sequence during the first semester is likely a result of the DCMP program's design, which allows students placing two or three levels below college-ready to enter into college-level math after passing only one semester-long developmental math course, Foundations, rather than the multiple semester-long courses that are generally required in the standard sequence at these colleges.

Impacts of the DCMP on students completing the developmental math sequence continued in later semesters even after standard group students had enough time to fulfill their full developmental math sequence requirements. Program group students were 25 percentage points more likely than their standard group peers to have completed their developmental math sequence by the end of the second semester, and 24 percentage points more likely to have completed the sequence by the end of the third semester. This measure reflects that program group students passed developmental math courses at higher rates, but also that the program accelerates the developmental sequence, compressing two semesters of developmental math into one class and allowing program group students the opportunity to pass more quickly into college-level coursework.

Impacts on College-Level Math

While passing developmental math is important, it is a step in the broader goal of succeeding in college-level math. Table 4.2 presents the findings on students' college-level math enrollment and pass rate during the second and third semesters.

- **Program group students were more likely to pass college-level math courses in the second semester, and that continued to be the case during the third semester.**

As can be seen in Table 4.2, by the end of the second semester, 20 percent of program group students had passed a college-level math class, compared with only 9 percent of the standard

[10]This measure includes students who successfully completed the highest-level math class and students who enrolled in a college-level math class. Students who enrolled in a college-level math class are included in this measure because students sometimes test out of developmental math prior to finishing the sequence. The only opportunity to capture these students in the data is when they enter a college-level math course.

Table 4.2

Impacts on College-Level Math Class Enrollment and Pass Rates

Outcome (%)	Program Group	Standard Group	Difference (Impact)	P-Value
<u>Second semester</u>				
Ever enrolled in college-level math class	28.3	10.8	17.5***	0.000
Ever passed college-level math class	19.5	8.5	11.1***	0.000
Ever passed college-level math, among enrolled	*70.1*	*73.8*		
Ever withdrew from college-level math class	5.4	1.3	4.1***	0.000
<u>Third semester</u>				
Ever enrolled in college-level math class	35.9	23.2	12.7***	0.000
Ever passed college-level math class	25.3	18.5	6.8***	0.002
Ever passed college-level math, among enrolled	*70.8*	*78.8*		
Ever withdrew from college-level math class	7.5	3.4	4.1***	0.002
Ever enrolled in second college-level math class[a]	6.9	4.0	2.9**	0.020
Ever passed second college-level math class[a]	3.2	1.6	1.5*	0.070
Sample size (total = 1,411)	856	555		

SOURCES: CAPR calculations using transcript data provided by Dallas County Community College District, El Paso Community College, and Trinity Valley Community College.

NOTES: Rounding may cause slight discrepancies in sums and differences.
Estimates are adjusted to account for the various community college campuses students attended and the four different semesters during which students were randomly assigned.
Outcomes shown in italics are nonexperimental. Statistical significance tests are not conducted on nonexperimental outcomes.
Statistical significance levels are indicated as: *** = 1 percent; ** = 5 percent; * = 10 percent.
[a] Researchers calculated enrollment in and passing of a second college-level math class as students who enrolled in or earned more than three credits in college-level math.

group students. While the gap in those who passed at least one college-level math class lessens by the third semester, there is still an almost 7 percentage point impact of the DCMP on passing college-level math. The DCMP program also had a positive impact on the percentage of students who passed a second college-level math class. While only 3 percent of program group students had passed a second college-level class by the end of the third semester, this was 1.5 percentage points more than the standard group.

A key factor of the impact on students ever passing college-level math is that the program is moving more students to enroll in college-level math more quickly. Twenty-eight percent of program group students had enrolled in college-level math by the second semester, while only 11 percent of standard group students had enrolled by that time, a 17 percentage point impact. At the end of the third semester, there was still an almost 13 percentage point impact of the DCMP on enrolling in college-level math.

While these data suggest that the DCMP is improving students' college-level math pass rate, more program group students withdrew from college-level math than standard group students. Program group students were 4 percentage points more likely to have ever withdrawn from college-level math by the end of the third semester than standard group students. It is difficult to interpret why more program group students withdrew. For instance, it could be that more program group students felt unprepared for college-level math, but it could also be for other reasons that the study cannot explain. However, even with this higher withdrawal rate, more program group students enrolled in and stayed in college-level math than standard group students.

"Ever Passed College-level Math, Among Enrolled" is a nonexperimental measure because most study participants (64 percent of program group students and 77 percent of standard group students) never enrolled in college-level math. Of those enrolled in college-level math by the third semester, a smaller percentage of program group students passed college-level math compared with the percentage of students in the standard group who passed college-level math. While, as noted above, more program group students enrolled in and passed their first college-level math class, this noncausal finding suggests that a larger percentage of program group students who were enrolled in a college-level math course struggled with the course compared with standard group students who were enrolled in a college-level math course. Some of these students withdrew from the course (as noted above) and others failed to pass the course. However, these analyses should also be treated with caution as they are exploratory and include a small portion of the overall sample of students.

A third key confirmatory outcome of the study and an important goal of the DCMP was supporting students in earning more college-level math credits.

- **DCMP students acquired slightly more college-level math credits during the first three semesters than their standard group counterparts.**

Table 4.3 displays students' total attempted and earned math credits after three semesters. On average, DCMP students earned 0.2 more college-level math credits than the standard group. While 0.2 credit is a small impact overall, the impact is concentrated in the one-fourth of program group students taking and succeeding in college-level math.

There is a negative impact on attempting developmental math credits, but given the accelerated format of the DCMP discussed above, it is not surprising to see that the standard group attempted more developmental math credits than the program group.

Impacts on Credit Accumulation and College Completion or Transfer

Table 4.3 also shows the impact of the DCMP on non-math credit acquisition and total credit accumulation.

- **While program group students earned a slightly higher number of non-math and total credits by the end of the third semester, these findings are not statistically significant and therefore inconclusive as evidence that the program had an impact on overall credit earning.**

However, notably, DCMP students earned more math credits while maintaining their non-math credit attainment. Earning more math credits did not negatively affect students' attempting and earning credits in other courses.

Table 4.3

Impacts on Credit Accumulation, After Three Semesters

Outcome	Program Group	Standard Group	Difference (Impact)	P-Value
Math credits attempted	5.1	5.2	-0.1	0.453
Developmental	3.8	4.4	-0.6***	0.000
College-level	1.3	0.8	0.5***	0.000
Math credits earned	3.1	2.8	0.3	0.112
Developmental	2.3	2.2	0.0	0.888
College-level	0.9	0.6	0.2***	0.003
Non-math credits attempted	17.6	16.9	0.7	0.285
Developmental	2.2	2.2	0.0	0.813
College-level	15.4	14.7	0.6	0.320
Non-math credits earned	12.3	11.8	0.5	0.402
Developmental	1.3	1.3	0.0	0.975
College-level	11.0	10.5	0.5	0.386
Total credits attempted	22.7	22.1	0.6	0.452
Developmental	6.0	6.5	-0.5**	0.031
College-level	16.7	15.6	1.1	0.114
Total credits earned	15.4	14.7	0.8	0.282
Developmental	3.5	3.5	0.0	0.948
College-level	11.9	11.1	0.8	0.235
Sample size (total = 1,411)	856	555		

SOURCES: CAPR calculations using transcript data provided by Dallas County Community College District, El Paso Community College, and Trinity Valley Community College.

NOTES: Rounding may cause slight discrepancies in sums and differences.
Estimates are adjusted to account for the various community college campuses students attended and the four different semesters during which students were randomly assigned.
Statistical significance levels are indicated as: *** = 1 percent; ** = 5 percent; * = 10 percent.

Ultimately, the DCMP program aims to support more students in successful degree completion. Table 4.4 takes an early look at the DCMP's impacts on certificate and degree receipt and four-year college enrollment after three semesters for the full sample of students in the study. Since it would not generally be expected that most students attain a degree or transfer to a four-year college within three semesters of starting community college — about 70 percent of study participants are first-time college students — and since this would be even less likely for students who start college needing to take developmental coursework, the study team also explored the impacts on these outcomes after four semesters (or two years of college) for the first three cohorts of students. Even looking at four semesters is a tight timeline for these longer-term outcomes, making these findings preliminary.

Table 4.4

Impacts on College Completion or Transfer

Outcome (%)	Program Group	Standard Group	Difference (Impact)	P-Value
After 3 semesters				
Received any degree or enrolled at 4-year college	7.6	7.6	0.0	0.988
Received a certificate	1.4	0.5	0.9	0.122
Received an associate's degree or higher	2.9	2.9	0.1	0.953
Enrolled at 4-year college	4.5	4.9	-0.4	0.758
Sample size (total = 1,411)	856	555		
After 4 semesters (first 3 cohorts only)				
Received any degree or enrolled at 4-year college	13.5	12.9	0.6	0.767
Received a certificate	2.4	0.6	1.7**	0.025
Received an associate's degree or higher	6.8	6.1	0.7	0.649
Enrolled at 4-year college	7.1	8.3	-1.2	0.457
Sample size (total = 1,178)	717	461		

SOURCES: CAPR calculations using transcript data provided by Dallas County Community College District, El Paso Community College, and Trinity Valley Community College, as well as data from the National Student Clearinghouse.

NOTES: Rounding may cause slight discrepancies in sums and differences.
Estimates are adjusted to account for the various community college campuses students attended and the four different semesters during which students were randomly assigned.
Statistical significance levels are indicated as: *** = 1 percent; ** = 5 percent; * = 10 percent.

- **There is little difference between the program and standard group students on the combined outcome of obtaining a certificate or degree or enrolling in a four-year college after three or four semesters.**

However, there is an almost 2 percentage point impact on students obtaining a certificate by the end of the second year of college for the subgroup of students in the first three cohorts. Still, very few students in either group (2 percent of program group students, and less than 1 percent of the standard group students) had earned a certificate by this time.

Impacts on Subgroups of Students

The study team also explored whether impacts of the DCMP on student outcomes were different for different groups of students. As noted earlier, these analyses are considered exploratory and are used to better understand the impacts on the full sample or to generate new hypotheses for future testing. In some cases, the subgroups are small, making subgroup analyses somewhat underpowered and less reliable than the full sample analyses. They defined subgroups based on:

- Students' math placement level (students who tested zero or one level below college level are compared with students who tested two or three levels below)

- Whether students planned to enroll in college on a full- or part-time basis
- The amount of time between students' high school graduation and when they started college (comparing those who attended within one year of graduation with those who delayed college for more than a year)
- Students' race and ethnicity
- Students' gender

Math Placement Test Level

As noted earlier in this chapter, standard developmental math sequences generally include a series of semester-long developmental math courses into which students are placed depending on their need. A student struggling with beginning algebra may be required to take and pass two (and in some cases even three) semester-long developmental math courses before entering into the credit-bearing college algebra course, while a student with less need may only be required to take and pass one developmental math course, and a student ready for college-level math can enter directly into a college-level, credit-bearing course. The colleges in this study tended to place students on the basis of a math placement exam administered before the students' first semester.[11] The exam score determines a student's placement, anywhere from three levels below college-ready to college-level in math. Table 4.5 compares the impacts of the program for students depending on their original score on the entrance exam. Specifically, it compares the impacts of the DCMP for students who tested at college level or one level below (higher performing) with those who tested two or three levels below (lower performing) on the math placement exam before entering college. The DCMP program was geared toward students who tested one or two levels below; most study participants (84 percent) tested two or three levels below in math.[12]

- **Program impacts appear to be concentrated within the group of students who were lower performing on the math placement exam, the group of students who stood to benefit most from the program.**

For the higher-performing group, the findings suggest a negative impact of the program on college registration by the third semester.[13] It is unclear why the program would have

---

[11]Texas community colleges used the Texas Success Initiative Assessment (TSIA) for the placement exam; however, colleges could also use ACT or SAT scores, if available, as a measure of college math readiness.

Students also had the option to retake the placement exam at any time. If students' scores reflected a higher level during a retake, they could move into the higher-level course without taking or passing the originally assigned developmental course.

[12]The study team collected the testing information used in these analyses after random assignment and may not reflect the information used by counselors at enrollment.

[13]While not shown in this table, this negative impact was also found at the end of the second semester, but the program and standard groups registered at similar levels during the first semester.

Table 4.5

Impacts by Math Placement Test Level, After Three Semesters

	College-Level or 1 Level Below				2 or 3 Levels Below				
Outcome	Program Group	Standard Group	Difference (Impact)	P-Value	Program Group	Standard Group	Difference (Impact)	P-Value	Differential Significance
Registered in third semester (%)	46.9	61.6	-14.7**	0.025	48.6	44.9	3.7	0.205	†††
Ever enrolled in developmental math class (%)	85.5	81.5	4.0	0.435	85.8	79.7	6.1***	0.005	
Ever passed developmental math class (%)	58.5	55.8	2.6	0.704	59.0	49.3	9.7***	0.001	
Completed developmental math sequence[a] (%)	60.3	54.3	5.9	0.390	56.5	29.2	27.3***	0.000	†††
Ever enrolled in college-level math class (%)	41.3	44.4	-3.1	0.653	34.9	19.0	15.9***	0.000	†††
Ever passed college-level math class (%)	30.4	40.5	-10.0	0.130	24.3	14.2	10.1***	0.000	†††
Math credits earned	3.4	3.5	-0.1	0.880	3.1	2.7	0.4**	0.039	
Developmental	2.3	2.1	0.2	0.580	2.3	2.2	0.0	0.903	
College-level	1.1	1.4	-0.2	0.370	0.8	0.5	0.3***	0.000	††
Total credits earned	15.9	19.3	-3.4*	0.073	15.4	13.7	1.7**	0.033	††
Developmental	3.0	3.2	-0.2	0.690	3.6	3.6	0.1	0.763	
College-level	12.9	16.1	-3.2*	0.062	11.7	10.1	1.6**	0.021	†††
Received any degree or enrolled at 4-year college (%)	11.5	8.6	3.0	0.486	6.9	7.3	-0.4	0.799	
Sample size (total = 1,411)	132	91			724	464			

SOURCES: CAPR calculations using transcript data provided by Dallas County Community College District, El Paso Community College, and Trinity Valley Community College, as well as data from the National Student Clearinghouse.

NOTES: Rounding may cause slight discrepancies in sums and differences.

Estimates are adjusted to account for the various community college campuses students attended and the four different semesters during which students were randomly assigned.

Statistical significance levels are indicated as: *** = 1 percent; ** = 5 percent; * = 10 percent.

Differential statistical significance levels are indicated as ††† = 1 percent, †† = 5 percent, † = 10 percent.

[a]Students are included in “Completed developmental math sequence” if they completed the highest-level developmental math class or enrolled in a college-level math class. It is possible under some circumstances for a student to enroll in college-level math without ever taking or passing a developmental math class (that is, students can retake the math entrance exam).

negatively affected these students' college attendance. It may be an unreliable result connected to the small sample size.[14] Since the colleges focused on recruiting students one or two levels below, only a small number of students (16 percent of the total sample) were in the higher-performing group. The difference in college registration may be one reason for program students in this group also accumulating fewer credits by the end of the third semester than their standard group peers.

For lower-performing students — those entering college with higher levels of developmental math need — the DCMP appears to have had a positive effect on their success in completing the developmental math sequence, their enrollment and pass rate in college-level math courses, and the number of college-level math credits they accrued. Interestingly, the DCMP program also appears to have a positive impact on the total credits earned by this lower-performing group. The program seems to be particularly effective for lower-performing students, with a positive impact even on students' non-math credit accumulation.

Full-Time or Part-Time Enrollment

Table 4.6 compares the impacts of the DCMP on outcomes for students who self-reported that they planned to attend college full time (taking 12 credits or more) compared with students who planned to attend college less than full time (taking fewer than 12 credits).

- **While the findings suggest that the program had a positive impact on both groups, the impacts appear to be larger for the group of students who planned to attend college less than full time.**

Specifically, the program seems to be somewhat more effective in supporting part-time students in completing the developmental math sequence, enrolling in college-level math, and earning college-level math credits. Traditionally, part-time students struggle more with academic performance and credit accumulation and are more likely to drop out than full-time students.[15] These findings suggest that the DCMP may be particularly helpful in supporting these students' math achievement. More specifically, 58 percent of part-time students in the program group completed the developmental math sequence by the third semester, a difference of 34 percentage points compared with part-time standard group students. Similarly, 57 percent of full-time program group students completed the developmental math sequence by the third semester, but for these students, the impact of the program appears to be about 18 percentage points. These findings suggest that the program may have been particularly successful in boosting part-time students' developmental math completion rates and bringing them in line with full-time students.

---

[14]The study team looked at the equivalence between the program and standard groups for this sample on a set of key baseline measures and found that while there were a few small differences in baseline measures between the program and standard groups, an overall test of the differences suggested the groups were similar.

[15]Chen (2007); Visher, Butcher, and Cerna (2010).

Table 4.6

Impacts by Whether or Not Student Planned to Enroll Full-Time, After Three Semesters

	Full-Time				Less than Full-Time				
Outcome	Program Group	Standard Group	Difference (Impact)	P-Value	Program Group	Standard Group	Difference (Impact)	P-Value	Differential Significance
Registered in third semester (%)	50.5	50.2	0.3	0.925	45.1	44.5	0.6	0.899	
Ever enrolled in developmental math class (%)	88.8	85.8	3.0	0.200	81.7	72.1	9.6**	0.010	
Ever passed developmental math class (%)	58.7	52.7	6.0*	0.088	60.3	46.5	13.8***	0.002	
Completed developmental math sequence[a] (%)	57.1	38.7	18.3***	0.000	58.6	23.9	34.7***	0.000	†††
Ever enrolled in college-level math class (%)	37.4	27.8	9.6***	0.004	35.2	15.1	20.1***	0.000	††
Ever passed college-level math class (%)	27.1	22.0	5.2*	0.089	23.4	11.8	11.6***	0.001	
Math credits earned	3.2	3.1	0.0	0.876	3.1	2.3	0.8***	0.001	††
Developmental	2.3	2.4	-0.1	0.628	2.3	2.0	0.3	0.103	
College-level	0.9	0.8	0.1	0.305	0.9	0.3	0.5***	0.000	††
Total credits earned	17.6	17.3	0.3	0.775	12.3	10.9	1.5	0.152	
Developmental	3.5	3.4	0.1	0.621	3.6	3.4	0.1	0.721	
College-level	14.0	13.9	0.2	0.856	8.7	7.4	1.3	0.124	
Received any degree or enrolled at 4-year college (%)	8.2	9.5	-1.3	0.521	7.2	5.4	1.8	0.408	
Sample size (total = 1,350)	513	313			313	211			

SOURCES: CAPR calculations using transcript data provided by Dallas County Community College District, El Paso Community College, and Trinity Valley Community College, as well as data from the National Student Clearinghouse.

NOTES: Rounding may cause slight discrepancies in sums and differences.
Estimates are adjusted by site-cohort interactions.
Statistical significance levels are indicated as: *** = 1 percent; ** = 5 percent; * = 10 percent.
Differential statistical significance levels are indicated as ††† = 1 percent, †† = 5 percent, † = 10 percent.
[a]Students are included in “Completed developmental math sequence” if they completed the highest-level developmental math class or enrolled in a college-level math class. It is possible under some circumstances for a student to enroll in college-level math without ever taking or passing a developmental math class (that is, students can retake the math entrance exam).

Time Between High School and College

The study team also explored the differences in impacts for students depending on whether they started college directly after high school graduation or delayed college for one year or more. While there were slight differences in outcomes in general for these two groups, with students who entered college directly having slightly better outcomes than those who delayed the start of college, there was little difference, and no statistically significant differences, in the program's impact on the two groups. Both groups saw similar positive impacts on completing developmental math and enrolling in and passing college-level math courses.

Race and Ethnicity

Given that students of color are overrepresented in developmental education courses,[16] the equity of program impacts and differences based on students' self-reported race and ethnicity are important. Table 4.7 displays the impacts after three semesters for white students, black students, and Hispanic students separately. As Chapter 1 notes, the majority of study participants were Hispanic (almost 54 percent), while 14 percent were white, and 13 percent were black. A large portion of students (17 percent) did not report their race/ethnicity or did not fully complete the questions on race and ethnicity on the study's baseline information form; these students were counted as missing and are not included in this subgroup analysis. Additionally, slightly over 2 percent of students self-reported a race and ethnicity other than white, black, or Hispanic and are not included in this analysis. Given the small sample sizes for white and black students, the findings in Table 4.7 should be interpreted cautiously. The four colleges also differed on the racial and ethnic makeup of their student bodies, and so differences in the implementation across schools could be correlated with differences in impacts between these groups.

- **The study team found few major differences in impacts among these three groups of students.**

The only exception is that while the study team found statistically significant impacts on "Ever passed a developmental math class" for white and Hispanic students, they found no impact on this measure for black students, and the difference between these subgroups on this measure is statistically significant.[17] It is not clear why this differential impact exists, but black students participating in the DCMP had lower pass rates for developmental math than white and Hispanic program participants. Similar to white and Hispanic students, black students participating in the DCMP were much more likely than their standard group counterparts to have completed the developmental math sequence by the end of the third semester.

---

[16]Chen (2016).

[17]The racial and ethnic makeup of the study participants was somewhat different across the four participating colleges, which means that this difference in impacts by racial and ethnic group could be correlated with the impacts by school. To explore this possible relationship, the study team tested the differences in impacts across the four colleges. While there was a statistically significant difference among the schools in whether students ever enrolled in a developmental math class, there was no statistically significant difference in impacts on the measure of whether students ever passed a developmental math course.

Table 4.7

Impacts by Race and Ethnicity, After Three Semesters

Outcome	Program Group	Standard Group	Difference (Impact)	P-Value	Differential Significance
White students					
Registered in third semester (%)	29.3	35.2	-5.8	0.410	
Ever enrolled in developmental math class (%)	90.0	87.7	2.2	0.635	
Ever passed developmental math class (%)	57.5	42.9	14.6*	0.057	†
Completed developmental math sequence[a] (%)	55.2	35.8	19.4**	0.011	
Ever enrolled in college-level math class (%)	35.3	24.4	10.9	0.124	
Ever passed college-level math class (%)	20.8	19.3	1.5	0.804	
Math credits earned	2.9	2.6	0.3	0.486	
Developmental	2.3	1.9	0.4	0.295	
College-level	0.6	0.7	0.0	0.828	
Total credits earned	12.9	13.5	-0.6	0.783	
Developmental	2.7	2.6	0.2	0.729	
College-level	10.2	11.0	-0.7	0.693	
Received any degree or enrolled at 4-year college (%)	8.6	3.8	4.7	0.214	
Sample size (total = 193)	118	75			
Black students					
Registered in third semester (%)	37.1	45.6	-8.5	0.297	
Ever enrolled in developmental math class (%)	86.2	90.7	-4.5	0.369	
Ever passed developmental math class (%)	38.5	47.8	-9.3	0.259	†
Completed developmental math sequence[a] (%)	40.2	21.9	18.3**	0.017	
Ever enrolled in college-level math class (%)	25.6	14.3	11.3*	0.098	
Ever passed college-level math class (%)	16.7	6.8	10.0*	0.072	
Math credits earned	1.9	2.1	-0.2	0.582	
Developmental	1.4	1.9	-0.6*	0.073	
College-level	0.5	0.2	0.4**	0.044	
Total credits earned	12.7	14.5	-1.7	0.430	
Developmental	2.8	3.5	-0.6	0.292	
College-level	9.9	11.0	-1.1	0.576	
Received any degree or enrolled at 4-year college (%)	7.4	7.2	0.2	0.967	
Sample size (total = 178)	120	58			

(continued)

Table 4.7 (continued)

Outcome	Program Group	Standard Group	Difference (Impact)	P-Value	Differential Significance
Hispanic students					
Registered in third semester (%)	58.9	56.2	2.7	0.459	
Ever enrolled in developmental math class (%)	90.8	87.9	3.0	0.191	
Ever passed developmental math class (%)	69.6	60.7	8.8**	0.012	†
Completed developmental math sequence[a] (%)	67.5	41.2	26.3***	0.000	
Ever enrolled in college-level math class (%)	43.4	29.9	13.5***	0.000	
Ever passed college-level math class (%)	31.6	25.2	6.4*	0.054	
Math credits earned	3.8	3.5	0.3	0.263	
Developmental	2.7	2.7	0.0	0.806	
College-level	1.1	0.8	0.3**	0.016	
Total credits earned	17.9	17.0	0.9	0.341	
Developmental	4.2	4.4	-0.2	0.566	
College-level	13.7	12.6	1.1	0.217	
Received any degree or enrolled at 4-year college (%)	7.3	7.3	0.0	0.985	
Sample size (total = 764)	465	299			

SOURCES: CAPR calculations using transcript data provided by Dallas County Community College District, El Paso Community College, and Trinity Valley Community College, as well as data from the National Student Clearinghouse.

NOTES: Rounding may cause slight discrepancies in sums and differences.
Estimates are adjusted by site-cohort interactions.
Statistical significance levels are indicated as: *** = 1 percent; ** = 5 percent; * = 10 percent.
Differential statistical significance levels are indicated as ††† = 1 percent, †† = 5 percent, † = 10 percent.
This table includes 81.1 percent of the study participants. Of the other 18.9 percent not included, 2.4 percent were identified based on administrative data from the colleges as a race/ethnicity other than white, black, or Hispanic; 16.5 percent were missing race and ethnicity information.
[a]Students are included in "Completed developmental math sequence" if they completed the highest-level developmental math class or enrolled in a college-level math class. It is possible under some circumstances for a student to enroll in college-level math without ever taking or passing a developmental math class (that is, students can retake the math entrance exam).

Gender

Finally, the study team explored the difference in impacts between male and female students. There were no statistically significant differences in the program impacts between female and male students. The program had a positive impact on both female and male students' completion of the developmental math sequence and their enrollment in and successful completion of their first college-level math course.

Reflections and Conclusion

This chapter shows that, overall, the DCMP had a positive impact on student outcomes. Program group students were able to move successfully out of developmental math more quickly, and substantially more program group students passed their first college-level math class during their first year in college compared with their standard group counterparts. Furthermore, the DCMP had a positive impact on students' math credit accumulation, and this success in math did not lead to neglect of other coursework. While the subgroup analyses suggest that the program had some negative effects for higher-performing students on their persistence at the colleges and their overall credit accumulation, the DCMP appears to have positively affected total credit accumulation for lower-performing students. While there was no impact on students' college completion and transfer after two years, there was a small positive effect on students' certificate attainment.

While the impact study demonstrates that the DCMP program has greater overall effectiveness than the standard developmental math sequence, the study is not designed to disentangle the effects of the different components of the program. Two of the key elements of the DCMP are (1) the accelerated developmental course allowing students to complete their developmental math requirements in one semester regardless of their math placement level, and (2) changes to the course curriculum offering material that is more relevant to students' planned degrees along with changes to the pedagogy to create a more student-centered learning environment. While the study shows that these combined elements are effective, it is not possible within this study to examine the effectiveness of each of these components separately. Still, there are a couple of findings that offer some insights into this question.

As Chapter 3 explains, the findings from the student survey show that the DCMP had an impact on students' attitudes about the utility of the math they were learning. In particular, program group students were more likely to agree that they could use the math they were learning in their everyday life, and to understand how they would need math in their future compared with the standard group students. These findings suggest that the program did positively affect students' attitudes toward math, and it is likely that these attitudinal shifts were at least in part the result of changes in course content and pedagogy. It is also possible that the impact of the DCMP on students' decision to enroll in developmental math was in part the result of the different content in Foundations compared with that of the standard developmental math courses. Students may have felt more comfortable and confident in their ability to participate in Foundations than they would have in a Beginning Algebra or Intermediate Algebra course.

At the same time, the program appears to be more effective for those students testing two levels or more below college level on the math placement exam compared with higher-performing students. All program group students, regardless of level, were placed into the single-semester Foundations course that led directly into college-level math. This acceleration of the developmental math sequence for those lower-performing students likely played a role in these students reaching other milestones earlier, including passing their first college-level math course and attaining more college-level math credits. Since only the students who placed two or more levels below grade level benefited from the acceleration, and the impacts seem to be concentrated in this group, the acceleration of the math sequence appears to be an important factor in the program's impact. Still, it is also possible that the changes in content and pedagogy of Foundations could have had a stronger impact on lower-performing students (who were the intended recipients of the program) than on higher-performing students. While the acceleration may be a key factor in the success of the program, the content and pedagogy changes may have also contributed to the impacts on students' academic outcomes.

While the program as implemented had a positive impact on students' enrollment and success in college-level math courses and the program group students were much more likely to enroll in and pass college-level math than the standard group students, some program group students struggled with the college-level math courses and ultimately withdrew from or failed a college-level math class. The original design of the DCMP model included changes in pedagogy and content to both Foundations and the college-level courses using the DCMP curricula. But, as Chapter 3 notes, college-level DCMP courses were not widely available across the colleges, and only 23 percent of program group students who took a college-level math course in the second or third semester took a DCMP Statistical Reasoning or Quantitative Reasoning course, which was designed to complement Foundations. The pedagogy and curricula in the colleges' standard offerings of entry-level college math, including the colleges' standard statistics and quantitative reasoning courses, do not necessarily match as closely with the Foundations curricula, which may have made the transition into college-level math harder for some program group students and may account for some of the program group students' challenges with college-level math.

In sum, the study findings show that the DCMP is effective in helping students succeed in college math. Yet while the program is successful in moving more students through the developmental math sequence and into college-level math, many students still drop off at various places along the pipeline. Fifteen percent of program group students never took a developmental math course during the first three semesters of college, 43 percent of program group students never completed the developmental math sequence, and only one-fourth of the students assigned to the DCMP program successfully completed a college-level math course during the study period. The challenges these students face are not only related to math — less than 50 percent of the sample (both program and standard group students) were still enrolled at their original college by the end of the third semester and only about 13 percent of students had earned a certificate or degree or moved on to a four-year college by the end of their fourth semester. While the DCMP is an effective program compared with the standard developmental math sequence, it may need to be coupled with other programs or additional services to ensure that more college students struggling in math, and in college in general, can successfully complete college-level courses and attain degrees.

Chapter 5

Cost of the Dana Center Mathematics Pathways

This chapter discusses the start-up costs and net ongoing costs of the Dana Center Mathematics Pathways (DCMP) to the colleges, as well as start-up costs to the Dana Center. The DCMP model discussed in this chapter includes the implementation of the statistics and quantitative reasoning math pathways, respectively, and the revision of policies to support the growth of these pathways across the institution; the implementation of the Foundations for Mathematical Reasoning developmental math course and DCMP curricula in select college-level statistics and quantitative reasoning classes, which include revised math content and instructional models; and the revision of services such as advising and tutoring to support students' placement and success in these courses.[1] Start-up costs, as presented in this chapter, are estimates of the cost to initially implement the DCMP for the college and for the Dana Center to provide supports to colleges for DCMP implementation. Net ongoing costs include the additional cost of the DCMP to the college after its implementation, compared with the standard developmental math sequence. Colleges implementing similar policies care about both the initial costs to make the change to this model, as well as ongoing costs once the model is implemented. The information in this chapter could help colleges and policymakers budget for switching to the DCMP.

The key findings from this chapter are:

- The switch from standard developmental math to the DCMP's math pathways requires an initial investment. In this study, the average start-up cost per college over two years was about $140,450.
- Ongoing increase in costs to the colleges of DCMP over and above standard services is low. The net cost of running a DCMP program at the four colleges in this study averaged $19,340 per school per year.
- Start-up costs and net ongoing direct costs to a college from implementing the DCMP are fairly low.

Start-Up Costs to Colleges

The start-up costs associated with the DCMP's initial implementation were $140,450 per college over a two-year period on average, as shown in Table 5.1.[2] The average annual start-up cost per

---

[1]The DCMP is based around four principles that can be adapted to each institution's environment and needs. The DCMP model studied in this evaluation includes services and supports that may not be implemented by all DCMP colleges. For instance, the use of the DCMP curricula is optional. Though used by colleges in this study, other colleges implementing the DCMP may develop courses using their own internal curricula.

[2]All dollar values in this cost and cost-effectiveness analysis have been adjusted to 2018 dollars using the Higher Education Price Index for public two-year colleges. The analysis excludes all costs associated with the

Table 5.1

DCMP Start-Up Costs to Colleges Over Two-Year Start-Up Period

Cost Category	Average Cost per College ($)	Percentage of Total Cost (%)
Training		
Faculty	14,317	10.2
Advisors and counselors	18,287	13.0
Tutors	839	0.6
Other staff	51	0.0
Administration	81,907	58.3
Preparation	22,681	16.1
Other		
Materials	263	0.2
Travel	1,789	1.3
Total	140,450	100.0

SOURCE: CAPR calculations using cost data collected from colleges participating in the study.

NOTES: Researchers did not perform tests of statistical significance.
All dollar values have been rounded to the nearest whole dollar. Rounding may cause slight discrepancies in sums and differences.
These estimates calculate costs over a two-year start-up period.
All costs are shown in constant 2018 dollars.

college is less than 1 percent of the colleges' annual operating revenue, a fairly low cost to the college.[3] Most of these costs were for administration (58 percent of the total, or $81,907), which included any administrative support, ranging from planning which courses would be offered, revising math requirements for certain majors, aligning the courses, clerical support for the DCMP, and communications and leadership meetings about the DCMP. The second-highest cost is for training DCMP staff members (24 percent of the total); most of this training was for faculty members and academic advisors. Finally, the third-highest cost was for staff and faculty member preparation, which included activities such as time faculty members spent revising and preparing to teach DCMP courses. There were minimal costs for materials and travel.

Start-up costs per college varied. These costs ranged from $75,293 to $215,716 over two years. Although it is not possible to know with certainty the reason for differences in start-up costs, it is useful to theorize based on what is known about the colleges. One factor may be that

---

Center for the Analysis of Postsecondary Readiness's (CAPR's) evaluation of the DCMP. Start-up cost estimates are based on cost information reported to CAPR by the colleges. CAPR researchers developed a cost data-collection tool that was completed with the colleges and included follow-up conversations with the colleges. Costs of training are based on two years of data; costs of administration and preparation are based on one year of data applied to two years; and costs of materials and travel were for the period reported by the college (which varied) applied to two years. The data-collection period varied by college but included cost data spanning 2013 to 2016.

[3]Data from the National Center for Education Statistics' Integrated Postsecondary Education Database System (IPEDS) for the 2016-2017 school year were used to estimate start-up costs as a percentage of operating revenue. The average was 0.4 percent and ranged from 0.2 percent to 0.6 percent.

the start-up period varied by college. For example, El Paso Community College had the highest start-up costs in its initial two-year start-up phase (starting in 2013) in comparison with the other colleges. This was likely the result of El Paso's early adoption of the DCMP and involvement in helping the Dana Center co-develop and pilot the pathways and curricular materials. This included establishing faculty and staff member teams to work directly with the Dana Center and providing feedback on individual lessons, which may have resulted in higher start-up costs. In contrast, the lowest start-up costs were for Eastfield College, which implemented the DCMP last among the four colleges (in fall 2015, compared with Brookhaven and Trinity Valley Community College, which implemented the DCMP in fall 2014). At that point, presumably, the colleges could benefit from others' experience about best practices for the implementation of the DCMP. Another possible reason for El Paso's higher start-up costs could be its size: It is the largest college in the study and has multiple campuses.

Net Ongoing Costs of the DCMP to Colleges

The colleges were asked to provide information on costs and activities that occurred and went beyond what was needed for the standard developmental math sequence after the initial implementation of the DCMP (such as extra training for the DCMP, faculty stipends, administration, and materials); these costs are considered the net ongoing costs of the DCMP. For one school year, this cost averaged $19,340 per college, as shown in Table 5.2.[4] This average net ongoing cost per college is less than 1 percent of the colleges' annual operating revenue and, like the start-up costs, is a fairly low-cost activity for the college.[5] This estimate does not take into account changes in the amount of time required for student support activities such as advising, counseling, or tutoring.

The annual net ongoing cost per college ranged from $13,881 to $28,199. Higher costs did not necessarily correspond to a greater number of students in the DCMP; in fact, one of the colleges with higher costs had fewer DCMP students.

The main net ongoing cost is for faculty member training and stipends — 65 percent of total net ongoing costs. However, these costs vary from year to year. For example, one college did not have any new faculty members teaching DCMP courses that year and thus had no costs for faculty training and stipends.

The second-highest cost is administration: $3,815, or about 20 percent of total net costs. About 6 percent of total costs were for training activities for advisors, counselors, and tutors. Similar to faculty costs, there was variability by college on costs for other staff members, and it

[4]These costs are associated with the DCMP's steady state operation. Ongoing cost estimates are based on cost information for the 2016-2017 school year that the colleges reported to CAPR; CAPR researchers modified the data-collection tool that was used to collect start-up costs to be used for collection of ongoing costs. CAPR researchers also had follow-up conversations with the colleges about the cost data.

[5]Data from IPEDS for the 2016-2017 school year were used to estimate net ongoing costs as a percentage of operating revenue. The average was 0.1 percent and ranged from 0.05 percent to 0.15 percent.

Table 5.2

Estimated Annual Net Ongoing Cost of the DCMP

Component	Average Cost per College ($)	Percentage of Total Cost (%)
Faculty	12,499	64.6
Advisors and counselors	399	2.1
Tutors	769	4.0
Student ambassadors	1,221	6.3
Administration	3,815	19.7
Materials	635	3.3
Total net costs	19,340	100.0

SOURCE: CAPR calculations using 2016-2017 school year cost data collected from colleges participating in the study.

NOTES: Tests of statistical significance were not performed.
All dollar values have been rounded to the nearest whole dollar. Rounding may cause slight discrepancies in sums and differences.
Program costs are based on a steady state of operation that excludes external research and start-up costs.
All costs are shown in constant 2018 dollars.

is likely that costs would vary by year depending on the number of new staff members needing training. For example, one college hired student ambassadors — students paid to inform other students about the DCMP. The student ambassadors represented 6 percent of total costs across the four colleges but at that particular school they represented about one-third of the cost. Although student ambassadors were a significant cost, that school also had lower training costs for other staff members than the other schools. These differing investments reveal that colleges may make different decisions about the best way to implement the DCMP without increasing overall costs.

While a cost-effectiveness analysis requires data on costs per student, the DCMP's costs are not driven by the number of students participating. Therefore, that metric is not the most useful way to think about the added cost of the DCMP over and above standard developmental math. At $132, the average annual cost per student is fairly low. For comparison, this is lower than the $566 per-semester cost of the learning communities' interventions MDRC studied — another common approach to improving developmental education.[6]

[6]Typically learning communities designed for developmental education students in community colleges link two or more courses, at least one of which is a developmental course. Instructors typically communicate with one another at least once or twice during the semester to align and integrate the courses. Support services such as extra tutoring are often added to the program. See Visher et al. (2012) for more information.

Start-Up Costs to the Dana Center

The research team estimated the Dana Center's start-up costs at $295,057, as shown in Table 5.3.[7] The Dana Center played an important role in starting the DCMP in Texas and at the four colleges in this study. To implement the DCMP in a state, the functions performed by the Dana Center would need to be done either by the Dana Center or another party. Colleges implementing the DCMP in Texas received significant supports and assistance in aligning math pathways statewide, as well at their specific college. CAPR researchers estimated costs for a similar DCMP implementation assuming one state, four colleges, and a high level of services using the Dana Center's estimates of current costs for specific services. The Dana Center's costs vary based on a variety of factors, so many of the estimates were given as a range of costs.

In Texas, state support services made up the largest start-up cost to the Dana Center at 36 percent (or $106,249 at the midpoint of the 2018 cost estimate). State support services can include a range of activities and could vary by state. These services in Texas included tasks such as outlining the math requirements for different majors at public colleges and universities and assisting faculty members in developing recommendations for math pathways implementation appropriate for their college environment. It also included supporting math faculty members in revising their institution's math requirements for different majors. Additionally, the Dana Center worked with higher education boards to ensure that student assessment and placement requirements support a multiple math pathways system. CAPR researchers included a two-day workshop for colleges aimed at assisting college leaders in undertaking these tasks in this estimate.

Focused Online Collaborative Interaction Sessions (FOCI) represented 32 percent of the total start-up costs to the Dana Center (or $94,400). FOCI are highly interactive online learning sessions designed for instructors to share active and collaborative learning techniques that they can apply to math classes. FOCI provide additional supports for faculty members' implementation of these instructional strategies in the classroom.

College-level implementation of the DCMP curricula represented 26 percent of the start-up costs to the Dana Center (or $77,200). The Dana Center sought to support colleges' implementation of the DCMP by developing curricula that revised both classroom content and pedagogy. The DCMP curricula include full lessons and lesson guides for implementing more contextualized, student-centered active learning instruction for developmental math, statistics, quantitative reasoning, and pathway-to-calculus courses. The use of the DCMP curricula is not a requirement of colleges implementing these pathways, but they were important for the colleges in this study and thus are included here. CAPR assumed this support was delivered as a two-day workshop for college faculty and staff and three follow-up webinars.

The lowest start-up cost to the Dana Center was its workshop on transfer and alignment support, which represented 6 percent of start-up costs (or $17,208). Transfer and alignment

[7]Dana Center start-up costs were not adjusted for inflation; they are based on current costs and thus should already be in 2018 dollars.

Table 5.3

Estimated Start-Up Costs for the Dana Center's Work

Component	Rate ($)	Multiplier	Cost for implementation similar to DCMP ($)
State support services	65,000 - 95,000	1 state	65,000 - 95,000
State support services: two-day workshop	17,991 - 34,507	1 state	17,991 - 34,507
College-level implementation: two-day workshop & three webinars	19,300 - 19,300	4 colleges	77,200 - 77,200
Two cohorts of Focused Online Collaborative Interactive Sessions[a]	23,600 - 23,600	4 colleges	94,400 - 94,400
Transfer and alignment support: one-day workshop	17,208 - 17,208	1 state	17,208 - 17,208
Total			271,799 - 318,315
Midpoint of total cost			295,057

SOURCE: CAPR calculations using cost data from the Charles A. Dana Center.

NOTES: Researchers did not perform tests of statistical significance.

All dollar values have been rounded to the nearest whole dollar. Rounding may cause slight discrepancies in sums and differences.

Rates reflect current Dana Center rates at the time these data were gathered, rather than the rates at the time DCMP was implemented. Rates are reported as a range to reflect that many factors can influence the cost of Dana Center services. For example, workshop costs vary depending on the number of participants.

[a]Focused Online Collaborative Interaction Sessions (FOCI) are highly interactive virtual meetings designed to share active and collaborative learning techniques that instructors can use in mathematics classes. There is no travel required to participate in these online sessions.

support included working with multiple two-year and four-year colleges in the state in a one-day meeting to developing aligned math requirements across the participating institutions.

The Dana Center's functions and their associated start-up costs are necessary to implement the DCMP as it was done in this study. If a college or state were implementing a similar policy, another organization would likely need to take on these functions, even if the state did not work with the Dana Center. If the colleges tried to take on some of these functions, then its start-up costs would probably increase.

Conclusion and Next Steps

Whether the DCMP is cost-effective is an important question. The primary measure to assess cost-effectiveness in postsecondary education is to compare the net cost per college degree or certificate receipt for the intervention with the net cost per receipt for standard college courses and services. However, there is not yet enough follow-up data on the DCMP to allow this study to do a meaningful cost-effectiveness analysis. Nevertheless, the cost analysis has shown that, generally, the start-up and ongoing costs to the colleges are fairly low. In particular, the low net ongoing costs to the colleges under study make it more likely that the DCMP could be found to be cost-effective in the future because costs of the DCMP and standard developmental math curricula are similar. A cost-effectiveness analysis is a priority for future research, particularly when enough follow-up data are available that it would be reasonable to consider the effects of the DCMP on longer-term outcomes such as degree completion.

Chapter 6

Conclusion

Building an interest and engagement in math is critical to the future of the U.S. economy and students' ability to secure living-wage jobs. The labor market demands candidates with strong logic and critical thinking skills as well as the ability to interpret the myriad charts, graphs, and statistics integral to many workers' jobs.[1] As international studies have revealed, most American adults are currently unable to demonstrate these skills effectively, which makes their ability to get and keep these jobs much more difficult.[2] Such statistics reveal the dire need to find ways to improve people's understanding of math and how it applies to their everyday life and work.

The Dana Center Mathematics Pathways (DCMP), along with other multiple math pathways models, represents a bold step toward these goals. The revised pedagogy and math content in the DCMP developmental and college-level math courses provide multiple contexts in which students can engage with math content aligned with their career interests. Additionally, the more student-centered, active-learning-oriented pedagogies make students the primary actors in problem solving and sharing solution methods. The DCMP also introduces these learning techniques at the developmental level while accelerating developmental coursework so that students enter college-level math more quickly. Other multiple math pathways such as the Carnegie Math Pathways' Statway and Quantway, and the California Acceleration Project, also use these methods, suggesting that many in the field have seen the value of these changes to math instruction.[3]

Implementing such reforms is not easy. They often require change at multiple levels of postsecondary institutions — and at multiple institutions. In many cases, state or system policies need revision in order to assess and place students into appropriate course pathways. Advisors must align student math placement with programs of study while understanding various institutions' transfer and program requirements. The four-year colleges to which many two-year students transfer must agree with these course changes and accept that the coursework of these entering students fulfills their math requirements. Revised course content must be developed and approved by math faculty members and college leaders. Instructors must learn new teaching methods and have supports for implementing them consistently throughout the course. Such changes require work from multiple actors in colleges both within and across institutions.

This type of wide-ranging, multi-institution change goes beyond many developmental math reforms that have focused solely on changing the sequencing or structure of developmental courses and, as such, can present many challenges to implementation. However, advocates have

---

[1] Carnevale, Jayasundera, and Gulish (2015); Levy and Murnane (2004); National Association of Colleges and Employers (2017).

[2] Organisation for Economic Cooperation and Development (n.d.).

[3] Strother, Van Campen, and Grunow (2013); Hern (2013).

argued that these changes are worth the struggle, seeing that they help students progress more quickly and successfully through developmental and college-level math, accumulate course credits, and graduate at higher rates.[4] The evaluation of the DCMP by the Center for the Analysis of Postsecondary Readiness (CAPR) has sought to test this premise, adding to the growing literature on math pathways' promise for increasing college students' success. While it is not yet known whether the DCMP boosts credit earning and graduation rates, this chapter examines what the evaluation's findings suggest for policy, practice, and future research on developmental and college-level course reforms.

Can Math Pathways Improve Math Learning and Achievement?

When the Carnegie Foundation for the Advancement of Teaching, the Charles A. Dana Center, and multiple funders were first considering math pathways in 2009, the goals were ambitious. Math pathways, as articulated through the Statway/Quantway model, were expected to increase the number of developmental math students who earned college-level math credits in one year. The instructional aims were even higher. The changes embedded within the Statway/Quantway pedagogical models aimed for "more ambitious mathematical learning" that would "prepare students to persist to earn certificates and degrees." The pathways would do this by revising math courses to focus on statistics and quantitative literacy skills and on "conceptual understanding and the ability to apply mathematical skills in a variety of authentic contexts."[5] By virtue of new content and pedagogy, math pathways courses aimed to "help students understand the world around them" and would "be useful in a growing number of occupations and professions."[6]

Ten years later, the evidence is still relatively thin as to whether these grand objectives for math pathways have been met. Some studies have shown that math pathways help students increase their academic performance. For instance, an experimental study of a corequisite math pathway model, which allowed students with developmental needs to enroll directly in college-level courses with supports, has shown that this model can help increase developmental students' success in college math and their accumulation of credits.[7] Additionally, a quasi-experimental study of Statway and Quantway suggests that this model may hold promise for improving students' credentialing rates.[8] However, to date, no studies have examined whether math pathways advocates' more ambitious goals of changing students' math learning and conceptual understanding of math have been met.

---

[4]Liston and Getz (2019); Strother, Van Campen, and Grunow (2013); American Mathematical Association of Two-Year Colleges (2018); Saxe and Braddy (2015).

[5]Strother, Van Campen, and Grunow (2013).

[6]Strother, Van Campen, and Grunow (2013).

[7]A quasi-experimental study using propensity score matching showed Statway students achieving more credentials than students in standard developmental courses (Norman, 2017). Logue, Watanabe-Rose, and Douglas (2016) is a randomized controlled trial study that showed increases in math pathways students' college-level math completion and accumulation of credits.

[8]Norman (2017).

While CAPR's evaluation of the DCMP cannot answer all these questions, it does help shed light on how math pathways may affect students' college progress and math learning. As in other math pathways research, this DCMP study reveals that these pathways can improve students' math completion. Paired with data from other studies, these outcomes present further confirmation that math pathways can increase developmental students' progress to and through a college-level math course.[9] Additionally, early impacts on certificate receipt also suggest that math may indeed play an important role in students' college completion. Given that many have argued that developmental and college-level math are among the most significant barriers to students' college completion, these findings are important.[10]

In addition to the overall effects on students' completion of math, exploratory analyses of outcomes by subgroup suggest that the DCMP may be useful for two populations of students who traditionally have more trouble persisting in college: those in need of multiple developmental courses and part-time students. This evidence suggests that multiple math pathways interventions may be one important way to help improve the success of these students.

This evaluation also reveals that math pathways with student-centered instructional models can help students have markedly different experiences with math learning in their classes. In survey responses, 59 percent or more of program group students noted that they always or often wrote out their reasoning, worked in small groups, and shared solution strategies with other students. The DCMP developmental class, Foundations of Mathematical Reasoning, also affected students' attitudes toward math and their perception of its difficulty. More program students reported understanding how math applies to their everyday life and how they will need it in their future, and students in the program group more often noted that the difficulty level of their math class was about right or less difficult than did students in the standard group.

Finally, the strength of the research model, as a random assignment study, provided further validation that these effects on students' experiences and outcomes are the result of the DCMP program and not chance. This gives additional weight to the potential these models have for improving developmental students' college success.

Continuing Opportunities to Improve Student Success

While the DCMP had many positive effects on students' success and learning, many opportunities exist for strengthening these models and further improving students' chances for success in postsecondary education. This section discusses these areas and how findings from this study shed light on these issues.

- **Understanding how math pathways may affect longer-term student outcomes requires more research.**

---

[9]Strother, Van Campen, and Grunow (2013); Logue, Watanabe-Rose, and Douglas (2016).

[10]Bailey (2009).

This study of the DCMP was able to follow the full sample of students for only three semesters after their entrance into the study. Although the data indicate that the DCMP shows promise for improving students' completion of developmental and college-level math, researchers need more data to see how these pathways may affect students' credit accumulation and completion of college.

- **Math pathways effects may be stronger if paired with other reforms, such as longer-term supports for students throughout their college careers.**

Students in the program group saw significant increases in their completion of developmental and college-level math, and early impacts suggest that the DCMP may have been effective in increasing students' receipt of a certificate. However, the lack of impacts on students' persistence and overall credit accumulation may indicate these pathways are not enough to keep students in college and progressing. Such findings also suggest that math pathways may be one reform among many that can improve students' success in college.

As with CUNY's math pathways model, pairing the DCMP with corequisite designs may further accelerate developmental students' success. In 2017, the Texas state legislature mandated a move to corequisite courses for higher-level developmental education students. In response, the Dana Center has created multiple materials to help colleges integrate this design with the DCMP. Previous research suggests that this may be a promising way to further support student success.[11]

Alternatively, educational institutions can pair the DCMP with more comprehensive college reforms such as CUNY's Accelerated Study in Associate's Programs (ASAP) or guided pathways. Rigorous studies of ASAP reveal that a more intensive intervention that focuses on students' success throughout their college trajectory produces significant impacts on measures that are difficult to achieve, such as graduation.[12] Similarly, the DCMP curricular model's focus on instructional changes, which are not a part of the CUNY ASAP model, also suggests that these reforms' impacts on student success may complement one another.

Guided pathways is another popular whole-college redesign that aims to help students explore their interests, choose a major, and create a step-by-step plan to graduation. In addition to curricular and pedagogical changes, colleges implementing guided pathways also create structures and supports to keep students on their path, intervene if the students encounter challenges, and prepare them to transfer to a four-year institution or to launch a career. Both guided pathways and math pathways emphasize the need to accelerate developmental education and to help students select a major early in college so they can take the necessary courses from the beginning (and math pathways is a feature of many high-quality guided pathways programs).[13]

---

[11]Boatman (2012); Logue, Watanabe-Rose, and Douglas (2016); Logue, Douglas, and Watanabe-Rose (2019).

[12]Scrivener et al. (2015).

[13]Jenkins, Lahr, and Fink (2017).

Many colleges, states, and systems are already moving forward with these types of comprehensive changes to developmental education and students' college experiences. At least 250 colleges and 10 states are currently implementing guided pathways models.[14] However, a national study of developmental education reform shows that some colleges are implementing these reforms on a relatively limited scale while others are not implementing them at all.[15] Thus, more needs to be done to help colleges bring these practices to scale.

- **Math remains a significant barrier for student success, even with more promising instructional models.**

While DCMP students saw significant increases in their completion of college-level math and earning of math credits, over 40 percent of DCMP students and over 65 percent of students in standard courses failed to complete their developmental math requirements after three semesters. Only 25 percent of DCMP students had successfully completed a college-level math course. Additionally, over 50 percent of students in both study groups had not reenrolled in college by their third semester. These statistics reveal that far too many students continue to struggle to complete math requirements, regardless of the type of instruction and content they receive, indicating that more needs to be done to support their success.

Additionally, although many students in the DCMP reported that their math class improved their enjoyment of math, math confidence, and understanding how math could be used, researchers found no significant differences in students' general confidence in math or enjoyment of math learning. This suggests that, while one math class may improve students' learning, much more is needed to improve students' desire to learn math and confidence in their ability to use these skills.

Fortunately, math leaders and advocacy organizations are looking for ways to address these needs. For instance, some centers, such as Patrick Henry Community College's SCALE institute, provide avenues for helping postsecondary instructors employ active learning techniques.[16] Additionally, the Dana Center has developed a new online professional development model, FOCI, which now works with groups of math instructors remotely on active learning techniques, effective questioning, designing group-worthy tasks, and promoting a learning culture.[17]

Similarly, some math organizations are seeking ways to bring new instructional practices to math classes. For instance, Growth Sector has developed a STEM (science, technology, engineering, and math) Core model that seeks to engage developmental math students in more contextualized and supported math instruction through a one-year program.[18] Similarly, the Dana Center's Reasoning with Functions I and II curricula for STEM majors provide many of the same

[14]Bailey (2017).

[15]Zachry Rutschow et al. (2019).

[16]For more information about SCALE, see http://scaleinstitute.com.

[17]For more information about the Dana Center's FOCI, see https://www.utdanacenter.org/our-work/higher-education/higher-education-services/foci.

[18]For more information about Growth Sector's STEM Core Network, see http://growthsector.org/thestem-corenetwork/stem-core.

instructional models as those in their statistics and quantitative reasoning courses. Research on these efforts may help practitioners in the field learn more about how to make math instruction more engaging.

- **Observations of standard math classes suggest that more reform is needed in postsecondary instructional methods.**

Student survey results also provide further insight into instruction in standard developmental math classes — and it is not a flattering picture, at least in the context of the practices recommended by math experts.[19] Unlike the DCMP courses, standard developmental math courses appear to have had very limited student-to-student interaction; less than one-fourth of students in the standard group noted consistently working with other students on problems (17 percent), working in small groups (16 percent), or explaining their work to other students (14 percent). Few of these students reported being asked to regularly write out their reasoning (20 percent), explain their work using math terminology (28 percent), or solve problems using information from real life (22 percent). Instead, most students in the standard group (59 percent) reported working alone on math problems.

Overall, these results confirm what previous studies on developmental math instruction — and math instruction in the United States in general — have shown, namely that students are rarely learning and demonstrating their math knowledge in ways that connect math with their real lives or with other students' learning.[20] Unfortunately, these practices continue to prevail, despite recommendations from national math organizations such as the American Mathematical Association of Two Year Colleges, the National Council of Teachers of Mathematics, and the Mathematical Association of America to discontinue these practices.[21] These student survey results demonstrate that the field has a long way to go to achieve math pathways experts' loftier goals of improving students' conceptual understanding of math and understanding of how they can use it in real-world contexts.

- **With concerted effort, it is possible to change students' experience with math.**

Many postsecondary reforms have shied away from attempts to change classroom instruction. Reticence to intervene in the classroom may in part result from a desire to preserve faculty members' autonomy, as well as from evidence that changing teachers' methods can be a very difficult.[22] Despite these factors, the Dana Center was able to develop a curricular model that instructors successfully implemented and that led to dramatic changes in students' math learning

[19]Mesa, Celis, and Lande (2014); Carpenter, Frank, and Levy (2003).

[20]Saxe and Braddy (2015); Hodara (2011); American Mathematical Association of Two-Year Colleges (2018).

[21]Saxe and Braddy (2015); National Council of Teachers of Mathematics (2018); American Mathematical Association of Two-Year Colleges (2018).

[22]Quint (2011).

experience. While some teachers had challenges in implementing parts of the curricula, by and large, many were able to provide a qualitatively different instructional experience for students.

Surprisingly, these changes required relatively limited training. Nearly all instructors participated in a multi-day training on the DCMP curricula with Dana Center staff, and many also voluntarily participated in online forums and mentoring to support the implementation. Many instructors also reported spending a lot of time preparing to teach these classes in their initial semester using the new instructional approaches. However, most were able to successfully make these changes in their first semester.

These findings provide a hopeful note for the field's chances for revising instructional practice in higher education settings. However, previous research also suggests that changing teaching practices — and even more important, student outcomes — can be difficult. For instance, two studies of an intensive professional development model for K-12 math and reading teachers found that it had inconsistent effects on teachers' knowledge and practices and had no impact on students' outcomes. Exploratory analyses confirmed that professional development can affect student outcomes but that instructional reformers must be attentive to how this new learning is enacted in the classroom.[23]

- **Particularly in higher education settings, the question of what methods of math instruction positively affect students' learning needs further research.**

This study is one of a few that has attempted to assess how an intervention to change instruction in developmental classes and how students' experiences in the classroom may affect their understanding, engagement, and enjoyment of math. While it offers some clear findings and lessons, it does not provide all the answers. Some of this may be a function of methodological challenges in postsecondary research. For instance, very few instruments exist to measure student learning and engagement in higher education, leaving most studies — this one included — to rely on more indirect indicators of learning, such as successful completion of classes and accumulation of credits. Alternately, it is challenging to measure improvements in learning or to discern which changes may be most critical for students' future success when the course content has changed. Additionally, rigorous studies of postsecondary interventions tend to examine multifaceted interventions, making it difficult to isolate whether certain aspects of a model are particularly effective. This study, for example, cannot disentangle the effects of instruction from other aspects of the DCMP, such as developmental course acceleration and the changes to course content.

Recent research on developmental education reform has shown that many structural and sequencing reforms, such as corequisite courses or compressed courses, hold promise for improving developmental students' outcomes.[24] However, most of these research studies have focused on helping students get through math. Far fewer have focused on effective ways to attract students

[23]Quint (2011).

[24]Cho et al. (2012); Daugherty et al. (2018); Edgecombe (2011); Jaggars, Edgecombe, and Stacey (2014).

to math and math-focused careers.[25] Additionally, developing new mechanisms for assessing students' learning and their application of math skills in real-life settings is needed to better understand whether and how the math that students learn is applicable to their lives and careers. The development of these new measures, and the research findings drawn from them, are the next frontier of how to improve students' math learning and engagement.

Conclusion

Many national math associations have taken up the call for revitalization and renewal of math instructional practices in postsecondary settings. These leaders urge math instructors to help students discover the joy in math learning and be able to apply these concepts in a diverse array of fields. The DCMP model and the changes that its curricular models have made to math instructional practice suggest that how students learn math can have an important effect on their math understanding and confidence. Additionally, rigorous research on program group student outcomes reveals that such practices can also improve students' math performance. These findings provide a strong dose of hope for improving adults' math learning — and the need to integrate such instruction in far more math courses across the country.

[25]Strother, Van Campen, and Grunow (2013).

Appendix A

Supplement to Chapter 3

Appendix Table A.1

College-Level Math Class Enrollment During the First Three Semesters

Outcome (%)	Program Group	Standard Group	Difference	P-Value
Enrolled in any college-level math	35.9	23.2	12.7***	0.000
DCMP Quantitative Reasoning	2.0	0.2	1.8***	0.002
DCMP Statistical Reasoning	6.1	0.9	5.2***	0.000
College Algebra	2.2	7.9	-5.7***	0.000
Standard college-level statistics	14.7	5.5	9.2***	0.000
Standard quantitative reasoning or other non-DCMP college-level math	14.2	11.3	2.9	0.103
Sample size (total = 1,411)	856	555		

SOURCES: CAPR calculations using transcript data provided by Dallas County Community College District, El Paso Community College, and Trinity Valley Community College.

NOTES: Rounding may cause slight discrepancies in sums and differences.
Estimates are adjusted by site-cohort interactions.
Statistical significance levels are indicated as: *** = 1 percent; ** = 5 percent; * = 10 percent.
Percentages will not sum to 100 because categories are not mutually exclusive.

Appendix Figure A.1

Sample Lottery and Scheduling Form Used to Advise Students Eligible for the Dana Center Mathematics Pathways

Academic advisors at a college participating in the CAPR evaluation of the Dana Center Mathematics Pathways (DCMP, formerly known as the New Pathways Project or NMP) used this form to advise students eligible for the program. As Chapter 3 explains, the colleges revised many of their degree and certificate programs to allow statistics or quantitative reasoning to satisfy their math requirements. To help communicate this change, CAPR researchers worked with the colleges to develop forms like the sample below to help advisors identify and place students in courses appropriate for their needs. Because the Dana Center had not yet developed a STEM pathway, students pursuing programs that require algebra were not eligible for the DCMP.

Student name: ______________________________________ Date: __________________

[COLLEGE] New Mathways Project — Lottery and Scheduling Form

Students are eligible for this study if they placed or tested into MATH 0303 or MATH 0305
***And* are pursuing one of the following majors at [these four-year colleges]:**

Associate of Arts (AA) Degrees
General (AA - GENL)
Arts (AA - ARTS)
Chicana/o Studies (AA - CHIC)
Comm./Advertising Public Relations (AA - COAP)
Comm./Journalism Mass Comm. (AA - COMM)
Comm./Radio and Television (AA - CORT)
Dance (AA - DANC)
Education*
English (AA - ENGL)
All Liberal Arts Majors**

Associate of Arts (AA) Degrees (continued)
Multidisciplinary Studies (AA - EDUC)
Philosophy (AA - PHIL)
Speech (AA - SPCH)
Theater (AA - THEA)

Associate of Applied Science (AAS) Degrees/ Certificates of Completion
Medical Lab Tech (AAS - MLAB)
Nursing* (AAS - RNSG)**
Nursing-Paramedic to RN* (AAS - PMRN)**
LVN to RN Transition* (AAS - LVRN)**
Vocational Nursing* (C2 - VNSG)**
Surgical Technology (AAS - SRGT)
Advertising Graphics and Design (AAS - ARTC)
Fire Tech - Management (AAS - FIRE)
Interior Design Technology (AAS - INDS)
Sign Language/Interpreter (AAS - SLNG)

If student is interested in NMP, and does not have a registration hold, check one class in each group below:

NMP Program Group

- ☐ [CAMPUS] — MATH (0404), CRN
  Tuesday/Thursday [TIME]
  Instructor [NAME]
- ☐ [CAMPUS] — MATH (0404), CRN
  Tuesday/Thursday [TIME]
  Instructor [NAME]
- ☐ [CAMPUS] — MATH (0404), CRN
  Monday/Wednesday [TIME]
  Instructor [NAME]
- ☐ [CAMPUS] — MATH (0404), CRN
  Tuesday/Thursday [TIME]
  Instructor [NAME]
- ☐ [CAMPUS] — MATH (0404), CRN
  Monday/Wednesday [TIME]
  Instructor [NAME]
- ☐ [CAMPUS] — MATH (0404), CRN
  Tuesday/Thursday [TIME]
  Instructor [NAME]

- OR

Standard Group

- ☐ College Prep Math
- ☐ Introductory Algebra
- ☐ Intermediate Algebra
- ☐ Precalculus I College Algebra and Geometry
- ☐ Introductory Mathematics for Business and Social Science
- ☐ College Mathematics
- ☐ Math in the Modern World
- ☐ Fundamentals of Statistics

References

AACC Pathways Project. n.d. "The Movement Toward Pathways." Website: https://www.aacc.nche.edu/wp-content/uploads/2017/09/TheMovementTowardPathways.pdf.

Achieving the Dream. 2018. "2018 Designing Math Pathways: Building Institutional Capacity and Sustainability in Math Redesign." Conference Presentation. Pittsburgh, PA: Achieving the Dream.

American Mathematical Association of Two-Year Colleges. 2018. *IMPACT: Improving Mathematical Prowess and College Teaching*. Memphis, TN: American Mathematical Association of Two-Year Colleges.

Bailey, Thomas. 2009. *Rethinking Developmental Education in Community College*. New York: Community College Research Center, Teachers College, Columbia University.

Bailey, Thomas. 2017. "Guided Pathways at Community Colleges: From Theory to Practice." *Diversity & Democracy* 20, 4.

Bailey, Thomas, Dong Wook Jeong, and Sung-Woo Cho. 2010. "Referral, Enrollment, and Completion in Developmental Education Sequences in Community Colleges." *Economics of Education Review* 29, 2: 255-270.

Barnett, Elisabeth A., Peter Bergman, Elizabeth Kopko, Vikash Reddy, Clive R. Belfield, and Susha Roy. 2018. *Multiple Measures Placement Using Data Analytics: An Implementation and Early Impacts Report*. New York: Center for the Analysis of Postsecondary Readiness.

Bettinger, Eric P. & Bridget Terry Long. 2009. "Addressing the Needs of Underprepared Students in Higher Education: Does College Remediation Work?" *Journal of Human Resources* 44, 3: 736-771.

Bickerstaff, Susan, Octaviano Chavarín, and Julia Raufman. 2018. *Mathematics Pathways to Completion: Setting the Conditions for Statewide Reform in Higher Education*. New York: Community College Research Center.

Boatman, Angela. 2012. *Evaluating Institutional Efforts to Streamline Postsecondary Remediation: The Causal Effects of the Tennessee Developmental Course Redesign Initiative on Early Student Academic Success*. New York: National Center for Postsecondary Research.

Burdman, Pamela, Kathy Booth, Chris Thorn, Peter Riley Bahr, Jon McNaughtan, and Grant Jackson. 2018. *Multiple Paths Forward: Diversifying Mathematics as a Strategy for College Success*. San Francisco: WestEd & Just Equations.

Carnegie Math Pathways. n.d. *WestEd*. "Mission and Approach." Accessed August 24, 2019. Website: https://carnegiemathpathways.org/mission-approach/.

Carnevale, Anthony P., Tamara Jayasundera, and Artem Gulish. 2015. *Good Jobs Are Back: College Graudates Are First in Line.* Washington, DC: Center on Education and the Workforce.

Carpenter, Thomas P., Megan Loef Franke, and Linda Levi. 2003. *Thinking Mathematically: Integrating Arithmetic & Algebra in Elementary School.* Portsmouth, NH: Heinemann.

Carpenter, Trudy G., William L. Brown, and Randall C. Hickman. 2004. "Influences of Online Delivery on Developmental Writing Outcomes." *Journal of Developmental Education* 28, 1: 14-18, 35.

Charles A. Dana Center. 2014. "Texas Higher Education Coordinating Board Approves Change to Texas Success Initiative (TSI) Rules to Aid Implementation and Scale of NMP." Austin, TX: Charles A. Dana Center.

Charles A. Dana Center. n.d. "Co-Requisite Support Materials." Accessed August 17, 2019. Website: https://www.utdanacenter.org/our-work/higher-education/higher-education-curricular-resources/co-requisite-support-materials.

Charles A. Dana Center. n.d. "Curricular Resources for Higher Education: Helping Students Become Stronger through Research-Based Content and Pedagogy." Accessed August 17, 2019. Website: https://www.utdanacenter.org/our-work/higher-education/curricular-resources-higher-education.

Chen, Xianglei. 2007. *Part-Time Undergraduates in Postsecondary Education: 2003-04 (NCES 2007-165)*. Washington, DC: National Center for Education Statistics.

Chen, Xianglei. 2016. *Remedial Coursetaking at U.S. Public 2- and 4-Year Institutions: Scope, Experience, and Outcomes*. NCES 2016-405. Washington, D.C.: National Center for Education Statistics, Institute of Education Sciences, Department of Education.

Committee on the Undergraduate Program in Mathematics of the Mathematical Association of America. 2004. *Undergraduate Programs and Courses in the Mathematical Sciences: CUPM Curriculum Guide 2004.* Washington, DC: The Mathematical Association of America.

Complete College America. n.d. "Math Pathways." Accessed August 24, 2019. Website: https://completecollege.org/strategy/math-pathways/.

Crawford, Michael L. 2001. *Teaching Contextually: Research, Rationale, and Techniques for Improving Student Motivation and Achievement in Mathematics and Science.* Waco, TX: CCI Publishing, Inc.

Dana Center Mathematics Pathways. 2014a. *Curriculum Design Standards: Selected Supporting Research*. Austin, TX: Charles A. Dana Center.

Dana Center Mathematics Pathways. 2014b. *Transfer and Applicability FAQ*. Austin, TX: Charles A. Dana Center.

Dana Center Mathematics Pathways. 2017a. *DCMP Curriculum Design Standards.* Austin, TX: Dana Center Mathematics Pathways.

Dana Center Mathematics Pathways. 2017b. *Texas Transfer Inventory*. Austin, TX: Charles A. Dana Center.

Dana Center Mathematics Pathways. n.d.(a). "Classroom Level - Planning & Implementing." Website: https://dcmathpathways.org/take-action/classroom-level/classroom-level-planning-implementing.

Dana Center Mathematics Pathways. n.d.(b). "The DCMP." Accessed August 17, 2019. Website: https://dcmathpathways.org/dcmp.

Dana Center Mathematics Pathways. n.d.(c). “The DCMP Model.” Accessed August 17, 2019. Website: https://dcmathpathways.org/dcmp/dcmp-model.

Dana Center Mathematics Pathways. n.d.(d). “Where We Work.” Accessed August 17, 2019. Website: https://dcmathpathways.org/where-we-work.

Daugherty, Lindsay, Celia J. Gomez, Diana Gehlhaus Carew, Alexandra Mendoza-Graf, and Trey Miller. 2018. *Designing and Implementing Corequisite Models of Developmental Education: Findings from Texas Community Colleges.* Santa Monica, CA: RAND Corporation.

Edgecomebe, Nikki. 2011. *Accelerating the Academic Achievement of Students Referred to Developmental Education.* New York: Community College Research Center, Teachers College, Columbia University.

Edgecombe, Nikki, and Susan Bickerstaff. 2018. “Addressing Academic Underpreparedness in Service of College Completion.” *Texas Education Review* 6, 1: 75-83.

Epper, Rhonda M., and Elaine DeLott Baker. 2009. *Technology Solutions for Developmental Math: An Overview of Current and Emerging Practices.* Seattle, WA: Bill & Melinda Gates Foundation.

Fike, David S. and Renea Fike. 2012. “The Consequences of Delayed Enrollment in Developmental Mathematics.” *Journal of Developmental Education* 35, 3: 2-10.

Givvin, Karen B., James W. Stigler, and Belinda J. Thompson. 2011. “What Community College Developmental Mathematics Students Understand about Mathematics, Part 2: The Interviews.” *MathAMATYC Educator* 2, 3.

Grubb, W. Norton. 1999. *Honored But Invisible: An Inside Look at Teaching in Community Colleges.* New York: Routledge.

Grubb, W. Norton. 2013. *Basic Skills Education in Community Colleges: Inside and Outside of Classrooms.* New York: Routledge.

Handel, Michael J. 2016. “What Do People Do At Work? A Profile of U.S. Jobs from the Survey of Workplace Skills, Technology, and Management Practices (STAMP).” *Journal for Labour Market Research* 49: 177-197.

Hayward, Craig, and Terrence Willett. 2014. *Curricular Redesign and Gatekeeper Completion: A Multi-College Evaluation of the California Acceleration Project.* Berkeley: Research and Planning Group for California Community Colleges.

Hern, Katie. 2013. *Toward a Vision of Accelerated Curriculum and Pedagogy: High Challenge, High Support Classrooms for Underprepared Students.* Oakland, CA: LearningWorks.

Hiebert, James. 2003. “What Research Says About the NCTM Standards.” Pages 5-23 in J. Kilpatrick, W. G. Martin, and D. Schifter (eds.), *A Research Companion to Principles And Standards For School Mathematics*. Reston, VA: National Council of Teachers of Mathematics.

Hiebert, James, and Douglas A. Grouws. 2007. “The Effects of Classroom Mathematics Teaching on Students' Learning.” In Frank K. Lester Jr. (eds.), *Second Handbook of Research on Mathematics Teaching and Learning: A Project of the National Council of Teachers of Mathematics*. Charlotte, NC: Information Age Publishing.

Hodara, Michelle. 2011. *Reforming Mathematics Classroom Pedagogy: Evidence-Based Findings and Recommendations for the Developmental Math Classroom*. New York: Community College Research Center, Teachers College, Columbia University.

Hoyles, Celia, Richard Noss, and Stefano Pozzi. 2001. "Proportional Reasoning in Nursing Practice." *Journal for Research in Mathematics Education* 31, 1: 4-27.

Jaggars, Shanna Smith, Nikki Edgecombe, and Georgia West Stacey. 2014. *What We Know About Accelerated Developmental Education.* New York: Community College Research Center, Teachers College, Columbia University.

Jaggars, Shanna Smith, Michelle Hodara, Sung-Woo Cho, and Di Xu. 2014. "Three Accelerated Developmental Education Programs: Features, Student Outcomes, and Implications." *Community College Review* 43, 1: 3-26.

Jenkins, Davis, Hana Lahr, and John Fink. 2017. *Implementing Guided Pathways: Early Insights From the AACC Pathways Colleges*. New York: Community College Research Center.

Jimenez, Laura, Scott Sargrad, Jessica Morales, and Maggie Thompson. 2016. *Remedial Education: The Cost of Catching Up*. Washington, DC: The Center for American Progress.

Levy, Frank, and Richard J. Murnane. *The New Division of Labor: How Computers Are Creating the New Job Market.* Princeton, NJ: Princeton University Press.

Liston, Cynthia, and Amy Getz. 2019. *The Case for Mathematics Pathways*. Austin, TX: Charles A. Dana Center.

Logue, Alexandra W., Daniel Douglas, and Mari Watanabe-Rose. 2019. "Corequisite Mathematics Remediation: Results Over Time and in Different Contexts." *Educational Evaluation and Policy Analysis*.

Logue, Alexandra W., Mari Watanabe-Rose, and Daniel Douglas. 2016. "Should Students Assessed as Needing Remedial Mathematics Take College-Level Quantitative Courses Instead? A Randomized Controlled Trial." *Educational Evaluation and Policy Analysis*.

MDRC. 2015. "Math Matters." Issue Focus (June). New York: MDRC.

Mesa, Vilma. 2012. "Achievement Goal Orientations of Community College Mathematics Students and the Misalignment of Instructor Perceptions." *Community College Review* 40, 1: 46-74.

Mesa, Vilma, Sergio Celis, and Elaine Lande. 2014. "Teaching Approaches of Community College Mathematics Faculty: Do They Relate to Classroom Practices?" *American Educational Research Journal* 51, 1: 117-151.

National Association of Colleges and Employers. 2017. *The Class of 2017 Student Survey Report.* Bethlehem, PA: National Association of Colleges and Employers.

National Council of Teachers of Mathematics. 2000. *Principles and Standards for School Mathematics.* Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. 2018. "NCTM Calls for Major Changes to High School Mathematics: Group Calls for End to Student and Teacher Tracking." News release, April 25.

National Research Council. 2001. *Eager to Learn: Educating Our Preschoolers.* Committee on Early Childhood Pedagogy: Barbara T. Bowman, M. Suzanne Donovan, and M. Susan Burns (eds.). Washington, DC: National Academy Press.

Norman, Jon. 2017. *Pathways Post-Participation Outcomes: Preliminary Findings*. Stanford: Carnegie Foundation for the Advancement of Teaching.

Organisation for Economic Co-operation and Development. n.d. *Key Facts About the Survey of Adult Skills (PIAAC)*. Paris, France: Organisation for Economic Co-operation and Development.

Program for the International Assessment of Adult Competencies, and Institute of Education Sciences National Center for Education Statistics. n.d. *PIAAC: What the Data Say About the Skills of U.S. Adults*. Washington, DC: National Center for Education Statistics.

Quint, Janet. 2011. *Professional Development for Teachers: What Two Rigorous Studies Tell Us*. New York: MDRC.

Richland, Lindsey E., James W. Stigler, and Keith J. Holyoak. 2012. "Teaching the Conceptual Structure of Mathematics." *Educational Psychologist* 47, 3: 189-203.

Saxe, Karen, and Linda Braddy. 2015. *A Common Vision for Undergraduate Mathematical Sciences Programs in 2025.* Washington, D.C.: The Mathematical Association of America, Inc.

Scrivener, Susan, Colleen Sommo, and Herbert Collado. 2009. *Getting Back on Track: Effects of a Community College Program for Probationary Students*. New York: MDRC.

Scrivener, Susan, Michael J. Weiss, Alyssa Ratledge, Timothy Rudd, Colleen Sommo, and Hannah Fresques. 2015. *Doubling Graduation Rates: Three-Year Effects of CUNY's Accelerated Study in Associate Programs (ASAP) for Developmental Education Students.* New York: MDRC.

Smith, John P. 1999. "Tracking the Mathematics of Automobile Production: Are Schools Failing to Prepare Students for Work?" *American Educational Research Journal* 36, 4: 835-878.

Stigler, James W., Karen B. Givvin, and Belinda J. Thompson. 2010. "What Community College Developmental Mathematics Students Understand About Mathematics." *MathAMATYC Educator* 1, 3: 4-16.

Stigler, James W., and James Hiebert. 1999. *The Teaching Gap: Best Ideas from the World's Teachers for Improving in the Classroom.* New York: The Free Press.

Strother, Scott, James Van Campen, and Alicia Grunow. 2013. *Community College Pathways: 2011-2012 Descriptive Report*. Stanford: Carnegie Foundation for the Advancement of Teaching.

Texas Higher Education Coordinating Board. n.d. Lower-Division Academic Course Guide Manual.

U.S. Department of Education. 2015. *Fact Sheet: Focusing Higher Education on Student Success.* Washington, DC: U.S. Department of Education.

Visher, Mary, Kristin F. Butcher, and Oscar S. Cerna. 2010. *Guiding Developmental Math Students to Campus Services: An Impact Evaluation of the Beacon Program at South Texas College.* New York: MDRC.

Visher, Mary G., Michael J. Weiss, Evan Weissman, Timothy Rudd, and Heather D. Wathington. 2012. *The Effects of Learning Communities for Students in Developmental Education: A Synthesis of Findings from Six Community Colleges*. New York: National Center for Postsecondary Research.

Weiss, Michael, Thomas Brock, Colleen Sommo, Timothy Rudd, and Mary Clair Turner. 2011. *Serving Community College Students on Probation: Four-Year Findings from Chaffey College's Opening Doors Program*. New York: MDRC.

Weiss, Michael, and Camielle Headlam. 2018. *A Randomized Controlled Trial of a Modularized, Computer-Assisted, Self-Paced Approach to Developmental Math*. New York: MDRC.

Weissman, Evan, Kristin F. Butcher, Emily Schneider, Jedediah Teres, Herbert Collado, and David Greenberg. 2011. *Learning Communities for Students in Developmental Math: Impact Studies at Queensborough and Houston Community Colleges.* New York: MDRC.

Whinnery, Erin, and Sarah Pompelia. 2018. *50-State Comparison: Developmental Education Policies.* Denver, CO: Education Commission of the States.

Yamada, Hiroyuki, Angel Bohannon, and Alicia Grunow. 2016. *Assessing the Effectiveness of Quantway: A Multilevel Model with Propensity Score Matching*. Stanford: Carnegie Foundation for the Advancement of Teaching.

Yamada, Hiroyuki, and Anthony S. Bryk. 2016. *Assessing the First Two Years' Effectiveness of Statway: A Multilevel Model with Propensity Score Matching*. Stanford: Carnegie Foundation for the Advancement of Teaching.

Zachry Rutschow, Elizabeth, and John Diamond. 2015. *Laying the Foundations: Early Findings from the New Mathways Project*. New York: MDRC.

Zachry Rutschow, Elizabeth, John Diamond, and Elena Serna-Wallender. 2017. *Math in the Real World: Early Findings from a Study of the Dana Center Mathematics Pathways*. New York: MDRC.

Zachry Rutschow, Elizabeth, and Alexander Mayer. 2018. *Early Findings from a National Survey of Developmental Education Practices.* New York: MDRC.

Zachry Rutschow, Elizabeth. 2019. *The National Academies of Sciences, Engineering, and Medicine Workshop on Understanding Success and Failure of Students in Developmental Mathematics: Developmental Mathematics Reforms.* Washington, DC: The National Academies of Sciences, Engineering, and Medicine.

Zachry Rutschow, Elizabeth, Maria Scott Cormier, Dominique Dukes, and Diana E. Cruz Zamora. 2019. *The Changing Landscape of Developmental Education Practices: Findings from a National Survey and Interviews with Postsecondary Institutions.* New York: Center for the Analysis of Postsecondary Readiness.

CAPR \ Center for the Analysis of Postsecondary Readiness

Teachers College, Columbia University
525 West 120th Street, Box 174, New York, NY 10027
P 212.678.3091 | @CAPR_deved
capr@columbia.edu | postsecondaryreadiness.org

CCRC COMMUNITY COLLEGE RESEARCH CENTER
TEACHERS COLLEGE, COLUMBIA UNIVERSITY

ccrc.tc.columbia.edu | @CommunityCCRC

mdrc
BUILDING KNOWLEDGE TO IMPROVE SOCIAL POLICY

mdrc.org | @MDRC_News