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A Randomized Controlled Trial of a Modularized, Computer-Assisted, Self-Paced Approach to Developmental Math

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Abstract

Community colleges are a large sector of postsecondary education. In 2016-2017, the United States had nearly 1,000 public 2-year postsecondary institutions (community colleges), serving almost nine million students, representing 39% of all undergraduates. The majority of entering community college students require developmental (or remedial) math. Success rates in the developmental math course sequence and college more broadly are discouragingly low. Policymakers, practitioners, and researchers alike are eagerly searching for reforms to improve success rates, but there is a dearth of causal evidence on the effectiveness of most proposed reforms. We sought to answer the following question: What effect does a modularized, computer-assisted, self-paced approach to developmental math (compared with a more "traditional" direct-instruction course alternative) have on students' likelihood of completing the developmental math course sequence? Findings from a randomized controlled trial (n =1,403) are presented. The program was well implemented; however, we did not find evidence that this approach was superior to the "traditional" math class. Although these results are disappointing, they are important because modularization and self-paced computer-assisted instruction are popular reforms.

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Introduction

In the United States, community colleges play a vital role in advancing the nation's agenda to increase college degree attainment and technical skills training, as they serve a significant proportion of postsecondary education students. In 2016-2017, nine million students attended public 2-year colleges (community colleges), representing 39% of all undergraduates. The open admissions and relatively low cost of community colleges (compared with 4-year colleges and universities) have contributed to unprecedented access to postsecondary education. However, rates of successful degree completion leave much room for improvement. Nationwide, among first-time, full-time community college students in the 2013 cohort, only 25% graduated within 3 years (Ginder, Kelly-Reid, & Mann, 2017).

One of the greatest challenges facing community colleges is that most entering students (approximately 59%) are deemed academically underprepared for college-level math and are referred to developmental math courses (Chen, 2016). These courses are intended to prepare students for college-level work; however, most students who place into remedial math courses never complete them, move on to introductory college-level math courses, or earn a degree (Bailey, Jenkins, & Leinbach, 2005; Bailey, Jeong, & Cho, 2010; Attewell, Levin, Domina, & Levey, 2006).

While the low success rates of students who place into developmental education are well documented (Bailey, Jeong & Cho, 2010), there is a dearth of causal evidence on the effectiveness of strategies to improve outcomes for these students. In fact, the U.S. Department of Education's What Works Clearinghouse (WWC) recently published a practice guide of strategies to help postsecondary students in developmental education, and after reviewing 25,697 studies, only 10 met the WWC evidence standards with or without reservations. Moreover, of the six practices recommended in the guide, only three had *any* evaluations meeting the WWC evidence standards supporting them, indicating that postsecondary administrators and policymakers desperately need causal evidence of strategies to improve developmental education (Bailey et al., 2016).

The present study contributes to this literature via a rigorous evaluation of a widespread type of developmental education reform — the division of remedial math courses into discrete, single-unit modules, in which the content is delivered via self-paced, computer-assisted instruction. The popularity of this type of reform extends from statewide policies to independent creation of homegrown programs at individual colleges. A 2016 survey of a nationally representative sample of 911 2- and 4-year colleges in the United States found that 40% of institutions offered self-paced approaches to developmental math education, and 32% of colleges used computer-based learning to support underprepared students (E. Zachry Rutschow & A. K. Mayer, personal communication, February 6, 2018). In the past few years, policymakers in Virginia and North Carolina independently standardized the developmental education curricula across all the colleges in their respective states and modularized their developmental math courses (Kalamkarian, Raufman, & Edgecombe, 2015).

At Tarrant County College (TCC) in Texas, math department faculty created ModMath, a modularized, computer-assisted, self-paced developmental math course sequence that was the subject of the present study. In this paper, we present findings from a 1,400-person randomized controlled trial of ModMath. The sections that follow provide context for the study, describe the program model and the theory of change, and detail the study's design and results. We conclude with a discussion on the implications of the findings.

Background and Study Context

Developmental Math at Tarrant County College

When the present study began, the developmental math sequence at TCC consisted of two courses: Developmental Math 1 and Intermediate Algebra. Students were placed into one of the two developmental math classes or into college-level math using the Texas Success Initiative (TSI) Assessment.[1] The courses were offered in a variety of course formats, including as lecture-based courses, computer-assisted lectures, Emporium (described later), and ModMath.

The focus of this paper is on the effectiveness of TCC's ModMath program. However, as Holland (1986) noted, "The effect of a cause is always relative to another cause" (p. 946). In other words, there is no singular effect of TCC's ModMath program — it depends what it is being compared with. In the present study, we examined the effectiveness of TCC's ModMath relative to the alternative developmental math course offerings at TCC. Table 1 provides a brief overview of ModMath and these alternative offerings, which is essential for understanding the service contrast and thus the effects we estimate. While the control group's experiences reflect some participation in all three alternatives, most control group students enrolled in lecture-based courses. In the Program Implementation section, we provide greater detail on participation in these alternative offerings, as well as students' experiences in these courses.

The next section describes the ModMath program model and the theory of change.

ModMath Model, Theory of Change, and Prior Research

Program Model

ModMath is a developmental math reform that changes the structure of the developmental math sequence and the instructional delivery of the curriculum, but not the course content itself. ModMath's course structure and instruction encompass four key components: (1) modularized courses, (2) computer-assisted instruction, (3) a diagnostic assessment, and

[1]Students may be exempt from taking the Texas Success Initiative Assessment if they obtain a certain score on their SAT, ACT, or Texas statewide high school test; have successfully completed a college-level math course; or are active or veteran members of the military.

Course Type	Sequence Structure	Instructional Delivery
ModMath	• Six 5-week modules • Each mod is 1 credit	• Computer-assisted instruction • Self-paced • Support from instructor and aide • Acceleration possible
Lecture-Based	• Two 16-week courses • Each course is 3 credits	• Instructor-led lectures • Instructor sets pace
Computer-Assisted Lecture	• Two 16-week courses • Each course is 3 credits	• Instructor-led lectures and computer-assisted instruction (varies by instructor) • Instructor sets pace
Emporium	• Two 16-week courses • Each course is 3 credits	• Computer-assisted instruction • Self-paced • Acceleration possible

Table 1. Features of Developmental Math Course Offerings at Tarrant County College

(4) on-demand, personalized assistance. Table 2 depicts the ModMath theory of change or logic model. The first two columns describe each component of the program and associated practices. The last two columns list intended student outcomes, and the middle column explains the mechanisms through which each set of practices was hypothesized to improve outcomes for ModMath students. The following sections detail the program components and the theory of change and summarize current research on the efficacy of this type of developmental math reform.

Modular Courses: The core component of ModMath is a structural change that divides each of the two semester-long developmental math courses into three 5-week one-credit modules or "mods" (Mods 1–6). All six modules are offered in any given ModMath course section. Students typically enroll in three modules — the equivalent of one traditional developmental math course — each semester.

Computer-Assisted Instruction: ModMath's course content is delivered via Pearson's instructional software program called MyMathLab. Students meet in computer classrooms at regularly scheduled times and work independently through the course material using instructional videos, PowerPoint slides, or an online or hardcopy version of the textbook. Because instruction is self-paced, students may accelerate and complete more than three modules in a given semester.

Diagnostic Assessment: To place students into one of the six computer-assisted modules, ModMath supplements the college's standard math placement test — the TSI Assessment — with an additional placement exam, Pearson's MyMathTest.[2] MyMathTest is intended to be more fine-tuned, or precise, than TCC's standard placement exam to place students in a module

[2]The exam, which is developed using Pearson's MyMathTest platform, allows faculty to create a customized placement exam by selecting questions from the software's test bank of problems that align with TCC's developmental math curriculum.

Table 2. A logic model for ModMath: components, practices, mechanisms, and outcomes.

Component	Key Practices and Features	Mechanisms	Student Outcomes: Short-Term Academic Progress	Student Outcomes: Long-Term Academic Progress
Diagnostic Assessment (MyMathTest)	• Fine-tuned for module placement • Aligned with course content	• Accurate placement resulting in close alignment of content with students' prior math knowledge	• Enrollment • Proportion of the developmental math sequence completed • College-level math course completion • Credits earned in subjects other than math	• College-level credits earned • Total credits earned • Persistence • Degree/certificate attainment • Transfer rates to 4-year colleges
Modularized Courses	• Each semester-long course divided into three 5-week modules • Each module worth 1 developmental math credit • Modules align with the standard curriculum	• Students earn one credit for each mod passed, resulting in sense of progress • Students who fail or stop attending a mod can repeat in the next 5-week session rather than wait until next semester to repeat whole course, resulting in increased persistence		
Computer-Based Instruction (MyMathLab)	• 100 percent of class time in computer lab • Various content delivery methods for instruction (video, presentation, text-book) • Mastery learning • Extra support available via software	• Allows for self-paced learning • Allows for completing up to 6 modules in a single semester • Students move on only after demonstrating mastery of material • Variety of content delivery methods and frequent assessments facilitate mastery		
Personalized, On-Demand Assistance	• Each class staffed with an instructor and aide • Instructor and aide circulate during class, providing one-on-one assistance	• Increases the amount of one-on-one instructor–student interactions, allowing more academic and emotional support		

Source: Adapted from Gardenhire, A., Diamond, J., Headlam, C., & Weiss, M. J. (2016). *Note*. The study looks at short-term academic progress (three semesters after random assignment).

that closely matches their demonstrated math knowledge and skill deficits. Students are then placed in one of the six modules, depending on their skill needs as determined by MyMathTest results, and must complete the remaining set of modules to complete developmental math.

On-Demand, Personalized Assistance: ModMath is designed so that instructors serve as facilitators who provide individualized support to students, as opposed to whole-group instruction. Each class, which typically enrolls 24 students, is staffed by an instructor and an instructional aide. Compared with traditional lecture-based courses, the highly personalized structure of ModMath provides more opportunities for instructional staff to provide one-on-one academic and emotional support to students.

Theory of Change

ModMath is theorized to improve student outcomes by addressing common challenges to developmental math instruction. A major pedagogical challenge in developmental math is that the courses typically serve students with a wide range of academic abilities, learning styles, and personal needs. Unless an instructor can accommodate these differences through differentiated instruction and other methods, such as supplemental academic support, students may fall behind, disengage, or fail (Tomlinson & Kalbfleisch, 1998). Several ModMath components allow for greater differentiation than is feasible in traditional lecture-based classrooms.

First, the modular structure, coupled with the fine-tuned diagnostic exam, is theorized to allow for more precise placement than the standard assessment used for traditional math courses. This granular type of assessment should allow students to enter a modular sequence at a level that is closely aligned with their prior knowledge, so that they focus only on topics in which they need remediation (Bickerstaff, Fay, & Trimble, 2016; Bracco et al., 2015). Second, ModMath tailors instruction to each student by combining computer-based learning via the instructional software package with on-demand, personalized assistance from the instructor and aide. This "hybrid" learning environment has been linked to improved student outcomes (Chekour, 2017; Means et al., 2009), although the evidence is mixed (Xu & Jaggars, 2011). Instructional software is thought to accommodate students with various learning styles and abilities by providing diverse instructional materials and allowing for self-paced instruction. Both features are intended to increase student engagement and performance (Goldschmid & Goldschmid, 1973; Subban, 2006). Furthermore, self-paced instruction should allow some students to accelerate and complete more than the standard three modules per semester.

In general, instructional software, such as MyMathLab, is theorized to facilitate optimal learning by placing students in Vygotsky's (1978) zone of proximal development — the developmental level where instructional content is just beyond students' current knowledge and students are capable of learning new material with assistance from a more knowledgeable tutor. In ModMath, this tutoring can come from the software, which includes several help features to guide students through new math problems, or from the instructor, who can fill in conceptual gaps or provide alternative methods of problem-solving to those provided by the software. Computer-assisted instruction is also theorized to facilitate mastery learning because it allows students to take frequent assessments, receive formative feedback on their learning, and progress only when they have mastered the material. This process is thought to improve student performance in developmental and in more advanced math courses (Bishop, 2010; Epper & Baker, 2009; Twigg, 2005).

Another common challenge to developmental math instruction is that many students often have a history of underperformance in math, suffer from math anxiety, or lack confidence in their mathematical abilities (Dwinell & Higbee, 1989; Taylor, 2006). By staffing each course with an instructor and an aide who provide individualized assistance, ModMath increases instructor-student interactions and allows opportunities for instructional staff to provide not only academic but also emotional support to students. This support may build students' confidence and improve their academic progress in math, as greater connections to staff can increase students' feelings of belonging and facilitate persistence (Tinto, 1999).

Finally, another challenge to developmental math instruction, especially in community colleges, is that many students stop attending classes or drop out for a variety of reasons. In traditional courses, students who drop out mid-semester do not receive any credit for already completed work and must restart the course from the beginning. The modularized structure of ModMath allows students to leave and return without losing as much ground. Furthermore, students using ModMath earn credits incrementally, which may give them a sense of accomplishment as they experience "small wins" (Weick, 1984) toward the goal of completing the entire developmental math sequence.

Effectiveness of Modularized, Computer-Assisted Developmental Math Programs

There is limited causal evidence on the efficacy of modularized, computer-assisted developmental math courses like ModMath. Much of the research relies on descriptive studies that examine academic outcomes, and the findings from these studies are mixed. For example, Squires, Faulkner, & Hite (2009) found that computer-assisted modules resulted in higher course pass rates in developmental math and subsequent college-level courses. On the other hand, Kalamkarian et al. (2015) studied North Carolina's and Virginia's modularized developmental math programs and concluded that pacing and attrition were major issues in self-paced, computer-assisted modules, as a significant portion of students did not complete the expected number of modules for the given semester. Ariovich & Walker (2014) found mixed results within a single study: students who opted to take modularized, computer-assisted developmental math performed worse in lower-level courses but better in higher-level courses, compared with students in lecture-based developmental math.

The mixed results of modularized, computer-assisted, self-paced developmental math courses may relate to variations in program implementation and institutional context. Fay (2017) concluded that high school students in Tennessee experienced higher pass rates than community college students using the same computer-assisted modularized developmental math program because the high schools had more structured classroom environments, such as rigorous attendance policies and frequent class meetings, than the community colleges, which were characterized by more flexibility and student autonomy. Bickerstaff et al. (2016) found that stand-alone modules (in which all students are in the same module) allow for instructional flexibility (as they can be taught via lecture or instructional software) but create additional exit points at which students may fail to reenroll in the next module. On the other hand, computer-assisted courses that offer several modules in one course section reduce the number of exit points but may slow student progression.

Importantly, the findings from all the aforementioned studies rely on descriptive research that does not use a comparison group. At least one quasi-experimental study has been conducted. Following a statewide redesign of remedial education in Tennessee, some community colleges divided their developmental math sequence into computer-assisted modules. Boatman (2012) evaluated two programs of this type and found similarly mixed results.

The inconclusive literature on modularized, computer-assisted courses highlights the need for a causal, experimental evaluation of the approach. The present study aims to begin to fill this gap.

Evaluation

Research Questions

The primary goal of the evaluation was to answer the following question:

- What effect does the opportunity to enroll in ModMath (compared with the opportunity to enroll in the college's "traditional" math courses) have on students' likelihood of *completing the developmental math course sequence*?[3]

We were also interested in any positive spillover effects or negative side effects on progress outside of math that may be caused by ModMath.

In addition to this overarching goal, we sought to understand several questions related to the implementation of ModMath and the "traditional" math courses with which ModMath is compared. They included:

- To what degree were ModMath services and activities implemented as planned (i.e., how strong was their fidelity to the program model)?
- To what degree were the services experienced by program group students different from those experienced by control group students (i.e., to what degree was there a contrast between the program and control conditions)?

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[3]This question and the implied primary outcome of interest were specified in an internal (i.e., not published) analysis plan written before to conducting analyses. The main outcome (confirmatory) of interest was having successfully completed the developmental math course sequence (for more on what is meant by "confirmatory," see Schochet, 2008).

The Study College: Tarrant County Community College, Texas

The study took place at Tarrant County College (TCC) District. With six campuses and an annual enrollment of about 50,000 students, TCC is one of the largest community college systems in Texas. This study took place at the Northeast Campus, located in Hurst, a suburb between Fort Worth and Dallas. The campus offers a range of associate degree programs that prepare students to enter professional careers or transfer to 4-year institutions. At the launch of this study, the Northeast Campus served approximately 15,000 students, and about 1,200 students were enrolled in developmental math education at the college (TCC Office of Institutional Research, Planning, and Effectiveness, as cited in Gardenhire, Diamond, Headlam, & Weiss, 2016).

Design

We used a random assignment research design to estimate the effect of the ModMath program compared with a "business-as-usual" control condition at the college, generally a more traditional, lecture-based course. Included in the evaluation were eligible students (those in need of developmental mathematics, based on placement test scores) who (a) were willing to participate in the ModMath program, (b) filled out a baseline survey, and (c) signed an informed consent.[4] After completing the baseline survey and informed consent, students were randomly assigned, through a computer algorithm controlled by the research team, to either the program or the control group. Program group members had the opportunity to participate in ModMath. Control group members had the opportunity to participate in any of the college's other developmental math course offerings and any support services, just not ModMath. Students had roughly a 60% chance of being assigned to the program group. Four cohorts of students were randomly assigned, one prior to the spring and fall semesters in 2014 and 2015. In total, 1,408 students were randomly assigned. Five students were not included in any analyses (two in the program group, three in the control group) because they withdrew from the study or their consent form was not recovered, leaving an analytical sample of 1,403 students.[5]

Data Sources

Data for this mixed methods evaluation came from qualitative and quantitative sources. These data sources are briefly described below; for more details, see Gardenhire et al. (2016).

Qualitative data were collected from focus groups with five groups of students (ranging in size from four to 20 participants), one group of ModMath instructors and one group of traditional developmental math instructors (17 participants, total), and one group of academic advisers (seven advisers). Interviews with 12 Tarrant County College staff members involved in the ModMath program were conducted. Finally, the research team informally observed ModMath classrooms 10 times and control group classrooms five times. The qualitative data were

[4]For more details on the recruitment process, see Gardenhire, Diamond, Headlam, & Weiss (2016).

[5]The overall attrition rate is 0.36% and the rate of differential attrition (the difference between program group attrition and control group attrition) is 0.28 percentage point.

used primarily to understand the program implementation and the experiences of program and control group members.

Quantitative data included a baseline survey (taken just before to random assignment, when students first enrolled in the study), TSI placement test records (used to determine developmental math course placement for most control group students), MyMathTest placement scores (used to determine module level for most program group students), student transcript records, and a student survey conducted during students' first semester after random assignment.[6]

Student Characteristics

As described above, upon joining the study, students completed a baseline survey covering information about their demographic characteristics, family and educational backgrounds, and experiences with math. As Table 3 shows, about 64% of students in the study were female. The study sample was 46% white, 28% Hispanic, and 20% black.[7] Many students in the study had characteristics associated with a low likelihood of academic success (Engle, 2007). For instance, a third of the students were the first in their families to attend college. Only 43% planned to enroll in school full time during the first study semester. Nearly three-quarters said that they planned to work during the upcoming semester, and about 44% planned to work full time. In addition, more than half of students reported that they had failed a math class in the past.[8]

Outcomes

The primary outcome of interest was completion of the developmental math sequence. To provide context when interpreting ModMath's effect on completing developmental math, several additional outcomes were examined. All outcomes are described briefly:

Participation: Two indicators of participation were considered:

- *Enrolled in college*. Enrollment was defined as of the add-drop deadline in a given semester.
- *Enrolled in any math class*. Enrollment in any math class was defined based on enrollment in a module *or* a math course in a given semester.

Developmental Math Progress/Completion: Several measures of developmental math progress and/or completion were examined:

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[6]The student survey had a 73% response rate, including program and control students.

[7]This sample reflects a gender and racial composition like that of Tarrant's overall student body.

[8]See Appendix A.1 in Gardenhire et al. (2016) for a comprehensive list of data reported by students on the baseline form, as well as a comparison of program and control group students on these measured characteristics. The two groups are strikingly similar on all characteristics.

Table 3. Characteristics of students in the study.

Characteristic (%)	Full sample (N = 1,389)
Female	64.3
Age	
18 and under	22.0
19–24	38.4
25–34	21.7
35–44	10.4
45 and over	7.5
Race/ethnicity	
Hispanic	28.3
White	45.7
Black	19.6
Other	6.5
Completed 12th grade	87.3
First person in family to attend college	33.7
Planned enrollment this semester	
Less than part time (fewer than 6 credits)	17.8
Part time (6–12 credits)	39.0
Full time (12 credits or more)	43.2
Planning to work this semester	
No	18.9
Yes, part time (less than 30 hours a week)	31.0
Yes, full time (30 hours a week or more)	43.6
Missing	6.6
Failed a math class in the past	53.5
Missing	6.7
TSI Math Placement	
College-ready or exempt	6.8
Placed one level below college-ready	9.1
Placed more than one level below college-ready	52.0
Math placement information is unknown or missing	32.1

Note. N = 1,389. Rounding may cause slight discrepancies in sums and differences. *Missing* shows the percentage of survey respondents who did not answer the question. Missing values are reported only for items with more than 5% missing. Calculations were made using data from the baseline survey of TCC students and TCC placement test data.

[a]Respondents who said they were Hispanic and chose a race are included only in the Hispanic category. Respondents who said they were not Hispanic and chose more than one race are included in the Other category. The Other category also includes respondents who chose Asian, American Indian, or Pacific Islander.

[b]Includes students who were found to be ready for college, who received waivers from testing requirements, who were exempt from testing requirements, or who had previously completed testing requirements.

[c]Includes students who were not included in the TCC placement test data.

- *Average percentage of developmental math sequence completed*. One indicator of progress was the percentage of the developmental course sequence completed.[9] Because students in ModMath can achieve smaller increments of success than students in traditional courses, this measure may favor the program group.

- *Earned at least 1 developmental math credit*. Another indicator that a student made any progress is whether he or she passed at least one module (one credit) or one course (three credits) since random assignment. Since students in ModMath can complete a one-credit module and students in traditional courses must complete an all-or-nothing three-credit course, this measure of progress favors the program group.

- *Completed first half of developmental* sequence. A final indicator of progress was whether students surpassed the halfway milestone in the developmental sequence — Mod 3 or Math 0361 (the lower-level developmental math course). This may be the fairest *progress* milestone comparison, since ModMath and the traditional course sequence have a similarly defined halfway point.

- *Completed developmental sequence (college-ready)*. The primary outcome of interest was completion of the developmental math sequence, which is defined as having passed Mod 6 or developmental Math 0362 since random assignment. Students who achieve this milestone are considered "college-ready" in math and may proceed to college-level course work.

Results

Program Implementation and Contrast Between Program and Control Conditions

Overall, we found that the program components were implemented with strong fidelity to the model and that the experience of the ModMath program group was different in anticipated ways from the experience of the control group.

ModMath courses were offered as discrete 5-week, one-credit modules, as planned, and more than 80% of students in the program group enrolled in a ModMath course during their first semester after random assignment. Classes were held in computer labs, and more than 70% of students randomly assigned to ModMath took the MyMathTest diagnostic exam to determine

[9]For example, a program group student who completed Mod 1 but not Mod 2 would be considered to have completed one-sixth of the developmental sequence, or about 17%. A student who completed Mod 2 but not Mod 3 would be considered to have completed two-sixths of the sequence, or about 33%. For control group students, a student who completed the developmental course Math 0361 (lower-level math) would have completed half of the sequence, or 50%, while a student who completed the developmental course Math 0362 would have fully completed the sequence.

their starting module. Instruction was delivered primarily via the MyMathLab software, and each class was staffed with an instructor and aide, who provided individualized assistance.

In comparison, the control group enrolled in semester-long, three-credit courses. There was variation in the types of courses control group students enrolled in. Approximately 57% of students enrolled in traditional lecture-based courses, and approximately 20% of students enrolled in one of the non-modularized alternative developmental math offerings, either computer-assisted lecture or Emporium. This is unsurprising, as control group students could enroll in any developmental math course type, except ModMath. Table 4 shows the percentage of students who enrolled in each course type. (For simplicity, we have classified computer-assisted lecture and Emporium as non-modularized computer-assisted courses.) Regardless of the type of course in which they were enrolled, all control group students had access to the MyMathLab software package, as the software was required for homework. In addition, students in non-modularized computer-assisted courses used MyMathLab for in-class instruction to varying degrees.

Table 4. First program semester math course type enrollment.

Outcome (%)	Program group (N = 826)	Control group (N = 577)	Estimated effect	Standard error
First semester				
ModMath	83.1	0.2	82.9***	1.6
Lecture based	2.1	56.9	-54.8***	1.8
Non-modularized computer assisted	0.5	20.4	-19.9***	1.4
Other[a]	1.1	3.0	-1.9***	0.7
No math course	13.3	19.6	-6.3***	2.0

Note. *N = 1,403*. Estimates are adjusted by cohort. Rounding may cause slight discrepancies in sums and differences.

[a]Includes math courses where the section type is unknown. Calculations made using transcript data from TCC.

***p = .01. **p = .05. *p = .10.

Even though students in both groups had similar access to the instructional software, classroom observation and student survey data confirmed a significant contrast between the classroom experience of ModMath program and control group students. ModMath instructors focused on providing one-on-one assistance during class. As shown in Table 5, 68% of ModMath students reported that their instructors spent a considerable amount, or most, of their time working individually with students during class, compared with only 32% of control group students. In contrast, the majority of non-ModMath instructors focused class time on whole-group instruction. Seventy-nine percent of control group students reported that their instructors spent a considerable amount, or most, of their time lecturing the class, compared with only 23% of ModMath students.

Accordingly, there was a significant difference in how students spent their time in math class. ModMath students worked individually on the instructional software. Table 5 shows that approximately 80% of ModMath students reported spending most of their time in class using

Table 5. Student survey results: instruction and assistance.

Response (%)	Sample size	Program group	Control group	Difference	Standard error
In your most recent math class, the instructor spent a considerable amount or most of the class period					
Lecturing the class	993	23.3	79.3	-56.0***	2.7
Working with small groups of students	992	22.8	25.0	-2.2	2.8
Working with students individually	992	67.6	31.7	35.9***	3.0
Giving announcements not related to math	989	12.4	14.4	-1.9	2.2
In your most recent math class, the students spent a considerable amount or most of the class period					
Working alone on math exercises	992	80.5	53.6	26.8***	2.9
Working in small groups on math exercises	991	7.3	12.9	-5.6***	1.9
Working as a class on math exercises	990	15.1	60.5	-45.4***	2.7
Chatting, texting, or on personal business	991	4.1	6.3	-2.1	1.4
Using computers, calculators, or technology	993	80.5	57.8	22.6***	2.9
Having problems with technology	993	2.5	5.9	-3.4***	1.2

Note. Total survey respondents *N = 1,012*. Total program group respondents *N = 620*. Total control group respondents *N = 392*. Estimates are adjusted by cohort. Rounding may cause slight discrepancies in sums and differences. Distributions may not add to 100% because categories are not mutually exclusive. Calculations made using data from survey of TCC students.

***p = .01. **p = .05. *p = .10.

computers, calculators, or technology and working alone on math exercises, while close to 60% of the control group reported similar experiences. This was expected, given that the question asked whether students used computers, calculators, or technology, and students in non-ModMath classes had time allotted for individual and small group exercises. Generally, control group students reported more whole-group instruction. Sixty-one percent of the control group report spending a considerable amount, or most, of their time working *as a class* on math exercises, compared with only 15% of the program group.

Taken together, these data highlight that ModMath offered students a more individualized class experience in which students spent significant time working independently on math exercises on their computers or being assisted by the instructor individually. In contrast, non-ModMath instructors spent a considerable amount of time lecturing the class, and students worked as a class on math exercises.

Evidence for ModMath's Theory of Change

We examined whether the expected benefits of certain program components (as outlined in the theory of change) were realized in practice.

Fine-tuned assessment and module placement. Modules in conjunction with the fine-tuned diagnostic exam did *not* allow the majority of ModMath students to bypass already mastered material and start in a higher module. Approximately 84% of students placed at the beginning of the math course sequence under both testing approaches — Mod 1 under MyMathTest or Developmental Math 1 under other placement tests. Since these students likely needed remediation in all the content covered by the developmental math curriculum, the opportunity to place into modules using MyMathTest did not make much of a difference.[10] Relevant context when considering this finding is that when ModMath first began, prior to the present study, TCC offered three developmental math courses and nine ModMath modules. Just before the start of the study, the lowest developmental math course was cut from the sequence due to a series of statewide policy changes, and the number of modules was reduced from nine to six. This change may have resulted in a greater number of students beginning the developmental math sequence in the lowest course or module, limiting the potential benefit of the diagnostic assessment.

Modularization and credit retention: As hypothesized (and shown later), the modular structure resulted in greater credit accumulation, as the program group earned more developmental math credits each semester compared with the control group, because they were able to earn one credit at a time (see Program Effects on Academic Outcomes section below). Focus group data suggest that this resulted in a greater sense of accomplishment. For example, one participant commented: "I've taken many, many remedial classes and haven't gotten anywhere because after a while I realized that I didn't have the core that I needed to move on. I'm almost finished with my college career here at TCC, and the only thing that's holding me back is the math requirements. So I was really upset that I had to start at the bottom [mod], but I will say I passed my first mod with an A, which I've never done that, so something must be working." This quote illustrates a common sentiment by focus group participants who received transcript credit mid-semester for passing a module. By facilitating these small wins, ModMath is theorized to result in improved developmental math completion. We examined whether this occurred in practice, as described below.

Content mastery. Because there was not a common final exam for program and control group students, the current study could not directly assess whether ModMath resulted in improved content mastery. It is important to note that ModMath students could attempt their exams without working through the module contents; however, they could not progress to the next module without passing the exams for their current module.

Self-paced learning and acceleration. Computer-delivered modules are theorized to improve student outcomes because they allow students to work at their own pace and potentially complete more than three modules in one semester. Our analyses revealed that acceleration was possible but not prevalent. Focus group participants often referred to the self-paced nature of ModMath as being beneficial in allowing them to slow down when learning the material, as opposed to accelerating and completing the sequence faster. For example, one student commented that with the video lessons, "you get to stop the teacher and keep going over and over [the material] until you get it, and you won't move on, and you won't get left behind because the teacher or class is moving on." This finding was confirmed by transcript data, which revealed that more ModMath students repeated modules, as opposed to accelerating and completing more than three modules in one semester (24% vs. 1%, respectively). This occurred even though instructors provided students with a pacing calendar that detailed the amount of

[10]MyMathTest did appear to alter placement for 16% of students: approximately 12% of students placed higher, and approximately 4% of students placed lower than under the college's standard placement exams.

work they needed to accomplish each day to complete the module in the allotted time frame and the full course by the end of the semester.

Although ModMath did not lead to student acceleration, the self-paced nature of the program may have resulted in students feeling that the difficulty of their course was appropriate. Approximately 71% of ModMath students reported that the level of difficulty of their math class was just right, compared with 51% percent of non-ModMath students.

Individualized instruction and student support. Based on interview and focus group data, ModMath increased one-on-one interactions between instructors and students, creating more opportunities for instructors to provide academic and emotional support to struggling students. ModMath focus group participants frequently compared their support experience in ModMath with their previous experience in lecture-based courses. For example, one student commented: "It's so much easier than lectures because I don't feel pressure to just hurry up and just understand it…I don't really like asking questions in front of a big group of people because I'm scared I'm gonna ask a stupid question." Most focus group participants felt that ModMath had increased their level of academic and personal support.

In general, ModMath services were largely implemented as planned and the program provided a notably different developmental math experience for students, compared with TCC's traditional lecture-based courses. There is evidence that some elements of the theory of change were realized in practice, while others were not. The next section discusses the program's impact on students' academic outcomes.

Program Effects on Academic Outcomes

This section presents estimates of the effect of ModMath on students' academic outcomes achieved over the course of three semesters after random assignment. Overall, ModMath was no more or less effective than traditional math. After three semesters, 23% of program group members had completed the developmental math sequence, the primary outcome of interest. Similarly, 22% of the control group had achieved the same milestone. On average, program group members completed a higher proportion of the six-credit developmental math sequence than did control group members. This was largely a result of the structural shift that allowed ModMath students to earn one credit for completing each of the six modules, whereas control group students earned credit only for completing the entire three-credit course. More details are provided below.

Enrollment, Progress, and Completion of Developmental Math

Table 6 presents information on students' enrollment at college and progress through and completion of the developmental math sequence. Table 7 presents academic progress in non-math courses to examine spillover effects. Findings are presented for the first three semesters after students were randomly assigned — meaning that, regardless of cohort of entry, we present findings for each student's first, second, and third semesters after entering the study. Recall that most

Table 6. Developmental math progress.

Outcome (%)	Program group (N = 826)	Control group (N = 577)	Estimated effect	Standard error
First semester				
Enrolled in college	93.1	90.2	2.9*	1.5
Enrolled in any math class (course or mod)	86.7	80.6	6.1***	2.0
Average percent of developmental math sequence completed	26.4	17.5	8.9***	1.4
Developmental math sequence progress since RA				
Earned at least 1 developmental math credit or higher	69.5	30.0	39.5***	2.5
Completed first half of developmental sequence	27.1	29.8	-2.7	2.4
Completed developmental sequence (college-ready)	2.2	5.1	-2.9***	1.0
Completed a college-level math course	0.4	0.3	0.0	0.3
Second Semester				
Enrolled in college	68.7	61.8	6.9***	2.6
Enrolled in any math class (course or mod)	51.4	40.3	11.2***	2.7
Average percent of developmental math sequence completed	37.9	27.1	10.9***	2.0
Developmental math sequence progress since RA				
Earned at least 1 developmental math credit or higher	72.4	38.4	34.0***	2.5
Completed first half of developmental sequence	40.6	38.2	2.4	2.7
Completed developmental sequence (college-ready)	14.7	15.7	-1.0	1.9
Completed a college-level math course	2.6	2.9	-0.3	0.9
Third Semester				
Enrolled in college	51.9	48.8	3.1	2.7
Enrolled in any math class (course or mod)	35.3	29.9	5.5**	2.6
Average percent of developmental math sequence completed	43.2	32.5	10.7***	2.1
Developmental math sequence progress since RA				
Earned at least 1 developmental math credit or higher	74.4	43.2	31.2***	2.5
Completed first half of developmental sequence	45.7	42.8	2.9	2.7
Completed developmental sequence (college-ready)	22.5	22.0	0.4	2.3
Completed a college-level math course	6.9	9.2	-2.3	1.5

Note. *N* = 1,403. *RA* = random assignment. Estimates are adjusted by cohort. Rounding may cause slight discrepancies in sums and differences. The fall 2016 cohort has data only for part of the third semester. Calculations made using transcript data from TCC.

***p = .01. **p = .05. *p = .10.

Table 7. Cumulative non-math progress.

Outcome	Program group (N = 826)	Control group (N = 577)	Estimated effect	Standard error
One semester				
Non-math credits attempted	6.49	6.56	-0.07	0.22
Non-math credits earned	4.82	4.73	0.10	0.23
Two semesters				
Non-math credits attempted	11.76	11.67	0.10	0.43
Non-math credits earned	8.64	8.49	0.14	0.42
Three semesters				
Non-math credits attempted	15.49	15.16	0.33	0.61
Non-math credits earned	11.44	11.14	0.30	0.58

Note. *N* = 1,403. Estimates are adjusted by cohort. Rounding may cause slight discrepancies in sums and differences. The fall 2016 cohort has data only for part of the third semester. Calculations made using transcript data from TCC.

***p = .01. **p = .05. *p = .10.

program group members needed to pass all six modules and most control group members needed to pass two developmental math courses to complete the developmental math sequence; thus, three semesters provide a reasonable amount of time for students to achieve the goal of completing the developmental math sequence, although many students may take longer. Findings are presented semester by semester.

First semester. Immediately after random assignment, 93.1% of the program group and 90.2% of the control group enrolled at Tarrant County College. The difference, 2.9 percentage points, represents ModMath's estimated effect on getting students to enroll in college.[11] This may reflect program group students' preference for having been given the opportunity to participate in ModMath or control group students' disappointment at not being offered the opportunity to participate in ModMath. Alternatively, it may be the case that ModMath staff were more likely to conduct personal outreach to program group students to ensure they enrolled than were non-ModMath staff for control group students.

In addition to this small positive effect on enrolling in college, students offered ModMath were 6.1 percentage points more likely to enroll in a math class (a module or a course), than were their control group counterparts. In other words, assignment to ModMath caused an estimated 50 additional students to enroll in math (out of the 826 program group students).[12] This positive effect on attempting any math credits is intriguing, since, as noted by Bailey, Jeong, & Cho (2010), "More students exit their developmental sequences because they *did not*

[11] All analyses presented are intention-to-treat. The percentages represent least squares means, and the estimated effect was calculated using a linear regression model. For ease of exposition we refer to *the effect of ModMath*, although technically it is *the effect of the opportunity to participate in ModMath*. Similarly, we refer to *program and control group outcome levels*, although we are presenting *regression-adjusted least squares means*. See Appendix A for more details.

[12] Calculated as 826 × 0.061 = 50.

enroll in the first or a subsequent course than because they *failed or withdrew from* a course in which they were enrolled."

Notably, to be eligible for the study, students had to be willing to participate in ModMath, and the only way to get into ModMath was to enroll in the study. Students who preferred the traditional math course could simply enroll in it, without participating in the study. Thus, ModMath's positive effect on getting students to take a math class may apply only to the types of students in the evaluation and may not generalize to all students in the college who required developmental math, especially those who preferred the traditional course. Nonetheless, the offer of ModMath encouraged some additional students to at least attempt a developmental math class, which is a strong starting point.[13] However, the goal of ModMath is to help students progress through and ultimately complete the developmental math sequence. We turned to progress and completion next.

Program group students were much more likely to earn at least one developmental math credit (by passing a module or a course) than were their control group counterparts — an indication of at least some degree of progress. Nearly 70% of program group students completed at least one class (typically at least one 5-week, one-credit module), compared with only 30% of control group students (typically a semester-long, three-credit course). This 39.5 percentage point increase in earning at least one math credit occurred largely because ModMath students had the opportunity to pass smaller portions of the developmental math sequence, 5 weeks at a time, one credit at a time. In contrast, students enrolled in the traditional courses were in an all-or-nothing situation — they had to pass an entire 16-week course to earn three credits. This structural difference led to a substantial difference in the number of students who were able to make *some* formal progress in the developmental sequence by accumulating one or more developmental math credits during the first semester.

Relatedly, on average, program group students completed a higher percentage of the developmental math sequence than did control group students. By the end of the first semester, program group students had completed 26.4% of the developmental math sequence, whereas control group students had completed 17.5% of the sequence — for an estimated effect of 8.9 percentage points. The positive effect on the percentage of the developmental math sequence completed is also due, in large part, to students earning credit for completing one or two modules in a semester, rather than having to complete an entire three-credit course.

ModMath's positive effect on completing at least one math credit and on the percentage of the developmental math sequence completed is encouraging. However, this success is tempered by the fact that only 27.1% percent of the program group completed the first half of the developmental sequence (Mod 3) by the end of the first semester. Students in the traditional math sequence had a similar likelihood of success — 29.8 percent of the control group made it through the halfway point (Math 0361) in one semester. The negative 2.7-percentage-point estimated

[13]Like the small effect on initial enrollment in college, the reason for the positive effect on attempting a developmental math course is not certain. It may have been due to the appeal of the program, but it also may have been an artifact of the experiment.

effect is not statistically significant, but it is discouraging. Moreover, there is evidence that ModMath lowered the proportion of students who completed the developmental sequence (and were thus college-ready) during their first semester. Only 2.2% of program group students accomplished this goal, compared with 5.1% of control group students, for an estimated effect of negative 2.9 percentage points, representing around 24 people.

Finally, Table 7 shows that ModMath is neither helping or harming students in their non-math courses. This remains the same throughout the follow-up period.

In sum, after one semester the effects of ModMath were mixed. The program helped students make greater progress, on average, but program group students were no more likely than control group students to reach the halfway milestone, and they were slightly less likely to complete the full developmental math sequence. Does the "early win" of earning at least one math credit, achieved by nearly 70 percent of the program group, translate into larger gains in future semesters? We turned to this question next.

Second semester. Following their first semester of ModMath, 68.7% of the program group were still enrolled at Tarrant County College (with the option to continue taking ModMath). While this level of dropout (or stop out) is disappointing, it is an estimated 6.9 percentage point improvement compared with what would have occurred had program group students not been offered ModMath — a promising finding. Much like the first-semester enrollment effect, this finding may have to do with program group students' positive experiences in ModMath or the control group's disappointment at not being offered ModMath. In this case, the effect estimate is positive and highly statistically significant ($p = .008$), so it is unlikely a chance finding.

Regarding math progress and completion, during the second semester, program and control group students continued to make progress. On the positive side, ModMath again caused more students (11 percentage points) to enroll in a math class; students offered ModMath remained much more likely (34 percentage points) to have earned at least one math credit since the start of the study; and the program group maintained its advantage with respect to the percentage of the developmental course sequence completed (10.9 percentage points). However, ModMath had no discernable effect on causing students to achieve the key milestones of completing the first half of the developmental math sequence or completing the entire sequence and being deemed college-ready in math. Lamentably, only around 15% of the 1,403 students in the study became college-ready in math within two semesters. Most students either did not attempt all required developmental math courses/modules, failed one or more courses/modules, or did not re-enroll at Tarrant County College.

Third semester. Students were tracked through three semesters after they entered the study. Students in ModMath and the more traditional math course had almost identical rates of completing the developmental math course sequence (22.5 percent vs. 22.0 percent, respectively). This occurred even though program group students continued to attempt a math class (course or module) at a higher rate than their control group counterparts, and they maintained their advantage with respect to the percentage of the developmental math sequence completed. Nonetheless, when it came to three major milestones — completing the first half of the developmental math sequence, becoming college-ready in math, and passing the first college-level math course, there was no discernable difference between the outcomes of students offered ModMath and their control group counterparts.

Subgroups Findings

In addition to examining ModMath's overall average effects, we explored the programs' effects for different types of students — specifically, with respect to students' baseline comfort with technology, developmental need, intent to enroll full time, and intent to work full time — all of which were measured prior to random assignment. Table 8 presents findings by subgroup. For example, the first panel shows that ModMath's estimated effect on becoming college-ready in math after three semesters is 1.0 percentage point for students who self-reported being comfortable with technology at the start of the study and 0.1 percentage points for students who were not. The final column in the table, with p value 0.867, shows that these two effect estimates are not statistically distinguishable. Stated differently, the 0.9 percentage point difference (1.0–0.1) in effect estimates between these two groups could easily have occurred by chance if the program's true effects were the same for both groups. The rest of the table shows that there is not clear evidence that ModMath was more effective for any particular subgroups of students — effect estimates are mostly near zero, just like the overall average.

In summary, breaking the developmental math course sequence into six one-credit, computerized modules led ModMath students to make incremental progress toward completing the sequence. Despite this apparent advantage, the ModMath program is no more (or less) effective than the traditional developmental math course at helping students complete their developmental math requirements.

Limitations

This study is one, if not the only, experimental evaluation of a modularized, computer-assisted, self-paced developmental math program in a community college setting. As a result, it provides an internally valid estimate of the causal effect of such a program on students' completion of the developmental math course sequence.

One important limitation of the study is that we are unable to assess ModMath's effect on mastering course content, since program and control students did not take a common standardized exam or post-test, and it was beyond the scope of the project to ensure they did so.

Another limitation is that the present study's findings are specific to ModMath at Tarrant County College and may not generalize to other colleges with different institutional contexts, different alternative course offerings, or drastically different student populations. Moreover, students could enroll in ModMath only if they joined this study, while students could enroll in other course types without restriction. As a result, the findings presented here do not necessarily inform

Table 8. Percentages of students ready for college math in the third cumulative semester.

Characteristic (%)	Sample size	Percentage of students ready for college math: Program group	Control group	Estimated effects	Standard error	P-value for estimated effects	P-value for differential estimated effects
Comfortable with computers at baseline[a]							0.867
Comfortable	1,023	22.3	21.3	1.0	2.6	0.709	
Not comfortable	362	23.8	23.7	0.1	4.5	0.982	
N	1,385						
Number of levels placed below college math[b]							0.115
One level below or higher	221	31.3	33.5	-2.2	6.4	0.729	
Two levels below	190	21.6	29.9	-8.3	6.4	0.194	
Three levels below	541	20.2	14.4	5.7*	3.3	0.084	
N	952						
Intended to enroll full time at baseline[c]							0.950
Full time	594	24.7	24.0	0.7	3.6	0.845	
Not full time	777	21.4	20.4	1.0	2.9	0.734	
N	1,371						
Intended to work full time at baseline[d]							0.585
Full time	609	18.3	18.9	-0.6	3.2	0.863	
Not full time	432	26.7	24.4	2.4	4.2	0.579	
N	1,041						

Note. Rounding may cause slight discrepancies in sums and differences. Estimates are adjusted by cohort. A two-tailed t-test was applied to differences between research groups. The fall 2016 cohort has data only for part of the third semester. A student was defined as ready for college math when the student passed either the final course in the developmental math sequence or a college-level math course. Calculations made using data from the baseline survey of TCC students, TCC placement test data, and TCC transcript data.

[a]Comfortable with technology defined as students who responded as being “extremely comfortable” or “comfortable” when asked “how comfortable are you using computers to do school work?”

[b]Determined by the TSI placement test. One level below or higher includes students who were TSI exempt or had the requirement waived, previously met TSI requirements, and placed into college math or one level below college math.

[c]Intended to enroll full time defined as a student who intended to enroll in 12 credit hours or more during the semester in which he or she was randomly assigned.

[d]Intended to work full time defined as a student who intended to work 30 hours or more per week during the semester in which he or she was randomly assigned.

***p = .01. **p = .05. *p = .10.

†††p = .01. ††p = .05. †p = .10.

whether ModMath would be well suited for students with a strong preference for traditionally structured lecture classes; such students could experience ModMath differently and therefore have different academic outcomes.

Discussion

Increasing the academic success of students referred to developmental math courses is a pressing priority for community colleges. Modularized, computer-assisted, self-paced remedial math courses, such as ModMath, are a widespread reform currently being implemented at institutions across the nation; yet, limited causal evidence on the efficacy of this approach exists. The present study employed a randomized controlled trial to evaluate ModMath and found that ModMath is similarly effective at getting students through the developmental math sequence as other course formats, particularly traditional lecture-based courses.

Sometimes when an evaluation finds that an intervention was no more or less effective than the alternative, the lack of impact can be attributed to poor program implementation or a weak contrast between the program and control groups. This was not the case for this study — for the most part the program's services were implemented as planned by its designers, and there were significant differences between the classroom experiences of ModMath and control group students. Given this, we look to the theory of change for insight into the findings.

One potential explanation for ModMath's lack of positive impact is that some elements of the theory of change that were theorized to lead to improved student outcomes were not realized in practice. The fine-tuned diagnostic exam did not change placement for the majority of ModMath students; the self-paced modules did not result in student acceleration; and the small wins gained by earning credits incrementally did not increase completion of the developmental math sequence. We discuss each of these, in turn.

With regard to the diagnostic exam, it is possible that the curricular changes that shortened the sequence from three to two courses just before the start of the study muted the potential benefits of the fine-tuned assessment. While this may be the case, many colleges are beginning to rely on multiple measures to assess student readiness for college-level work, instead of relying on a single exam. Recent studies have shown that this reform may improve students' outcomes in math (Scott-Clayton & Belfield, 2015). For TCC, incorporating multiple measures of assessment (in addition to a placement exam) may better identify students who would succeed in a higher developmental math module or course.

With regard to self-pacing, we find that more ModMath students slowed down as opposed to accelerated, which is consistent with other research on self-paced computer-assisted courses. There is a tension among autonomy, mastery, and acceleration in modularized courses (Bickerstaff et al., 2016). Mastery learning requires students to meet certain benchmarks before moving forward in the curriculum, which will naturally lead to slower progression. Furthermore, since many developmental math students have a history of underperformance in math, and many community college students manage school with work and other personal responsibilities, such as childcare, the flexibility offered by a self-paced course makes it more likely that these students will progress slower as opposed to faster. While ModMath designers attempted to overcome this challenge by issuing pacing calendars to keep students on track, acceleration was not explicitly promoted. To promote acceleration in ModMath, and other self-paced courses, while addressing the academic and personal needs of developmental math students in community colleges, a triage approach may be necessary. Students who are more advanced or have more available time could be identified and explicitly encouraged to move faster, through personalized pacing calendars or other means.

Alternatively, developmental math acceleration strategies that tailor and align required content to students' academic interests, as opposed to expecting them to cover more material in less time, may be more feasible. These types of strategies are gaining in popularity and some are showing early signs of success. For example, a study of the Dana Center's Mathematics Pathways program, which reduces the required number of developmental math courses based on program of study, has shown early signs of positive impacts on college readiness (Zachry Rutschow & Mayer, forthcoming). Similarly, shifting required course content from algebra to statistics for students in non-STEM (Science, Technology, and Mathematics) majors is gaining in popularity. At least one randomized trial, which included co-requisite remediation in the math needed for the statistics course, found evidence of improved outcomes (Logue, Watanabe-Rose, & Douglas, 2016).

Regarding modularization, we found that ModMath's modular course structure resulted in greater credit accumulation and increased feelings of accomplishment for students, but that these small wins were not enough to get students to the finish line. The fact that only about 22% of students in either group completed the two-semester developmental math sequence in three semesters indicates that far too many students are struggling using either approach.

Given this, the fact that higher education institutions are searching for ways to get students through the developmental math sequence faster and that early experimental research shows more positive results for other types of interventions (i.e., math pathways and mainstreaming), we conclude that ModMath is not currently the most promising strategy for developmental math reform. It is, however, a solid alternative to traditional lecture-based courses, as it leads to similar outcomes. Thus, to accommodate individual student preferences, colleges could offer ModMath and expect results similar to those of lecture-based courses.

Appendix A

Estimation Model

To obtain a regression-adjusted estimate of the causal effect of the opportunity to participate in ModMath, we used the following general linear model:

$$(1) \qquad Y = \beta T + \boldsymbol{\gamma RB} + \varepsilon$$

where Y is the outcome of interest; T is a treatment assignment indicator, set equal to one if a student was assigned to treatment and zero otherwise; $\boldsymbol{RB}$ is a vector of four random assignment block indicators (one for each unique cohort in the study); and ε is a random error term. Estimated effects presented in the tables are the $\hat{\beta}$s for the relevant outcome. Analyses for all academic outcomes at all time points include all 1,403 students.

The probability of being assigned to the treatment group varied across random assignment blocks;[1] therefore, inverse probability of treatment weights were used to ensure an unbiased impact estimator. Weights were created as follows:

$$(2) \qquad w_{ij} = T_{ij}\left(\frac{T_{..}}{T_{.j}}\right) + \left(1 - T_{ij}\right)\left(\frac{1-T_{..}}{1-T_{.j}}\right),$$

where:

- $T_{ij} = 1$ if individual i in random assignment block j was assigned to the program group and 0 if assigned to the control group.
- $T_{.j}$ = the proportion of sample members in random assignment block j assigned to the program group (i.e., the average value of T_{ij} in random assignment block j); and
- $T_{..}$ = the proportion of all sample members randomly assigned to the program group (i.e., the average value of T_{ij} across all sample members).

[1]The observed proportions assigned to the treatment group, by chronological cohort, were 52%, 59%, 61%, and 60% percent, respectively.

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Founded in 1974 and located in New York; Oakland, California; Washington, DC; and Los Angeles, MDRC is best known for mounting rigorous, large-scale, real-world tests of new and existing policies and programs. Its projects are a mix of demonstrations (field tests of promising new program approaches) and evaluations of ongoing government and community initiatives. MDRC's staff members bring an unusual combination of research and organizational experience to their work, providing expertise on the latest in qualitative and quantitative methods and on program design, development, implementation, and management. MDRC seeks to learn not just whether a program is effective but also how and why the program's effects occur. In addition, it tries to place each project's findings in the broader context of related research — in order to build knowledge about what works across the social and education policy fields. MDRC's findings, lessons, and best practices are shared with a broad audience in the policy and practitioner community as well as with the general public and the media.

Over the years, MDRC has brought its unique approach to an ever-growing range of policy areas and target populations. Once known primarily for evaluations of state welfare-to-work programs, today MDRC is also studying public school reforms, employment programs for ex-prisoners, and programs to help low-income students succeed in college. MDRC's projects are organized into five areas:

- Promoting Family Well-Being and Children's Development
- Improving Public Education
- Raising Academic Achievement and Persistence in College
- Supporting Low-Wage Workers and Communities
- Overcoming Barriers to Employment

Working in almost every state, all of the nation's largest cities, and Canada and the United Kingdom, MDRC conducts its projects in partnership with national, state, and local governments, public school systems, community organizations, and numerous private philanthropies.