Improving Students' College Math Readiness

A Review of the Evidence

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The author gratefully acknowledges Lisa Reynolds, Oregon's Core to College Alignment Director, and Christopher Mazzeo, Director of REL Northwest, for their feedback on this article. This article is a summary of a literature review completed while the author was a postdoctoral research associate at the Community College Research Center. The literature review was funded by the Institute of Education Sciences, U.S. Department of Education, through Grant R305C110011 to Teachers College, Columbia University. The opinions expressed in this article and the literature review are those of the author and do not represent views of the Institute or the U.S. Department of Education. For the full report, please visit the Center for Analysis of Postsecondary Education and Employment: http://capseecenter.org/publications/capsee-publications.

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October 2013

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Abstract

A major challenge facing students as they pursue a postsecondary degree is a lack of academic preparedness for college-level math, evidenced by high rates of referral to developmental math and low rates of college math completion. This study reviews rigorous research on the interventions and reforms that postsecondary institutions currently employ to address academic underpreparedness in math and to foster college math success. The interventions and reforms fall under three strategies: (1) intervening prematriculation with early assessment programs, bridges, boot camps, and brush-ups; (2) reforming developmental math; and (3) improving math instruction.

While the evidence is limited, many of these interventions appear promising. In terms of programs that intervene prematriculation, the study found that an early assessment program decreased students' likelihood of placing into remedial math, and a summer bridge program improved students' college math completion in the short term. The effects of developmental math reforms vary with some models having a more substantial impact than others. While modularization and learning communities had no long-term impact on students' outcomes, shortening the developmental math sequence improved students' college math enrollment and completion. Mainstreaming improved students' overall credit accumulation and, in one study, degree completion. Finally, in terms of innovations that are strictly pedagogical, using structured forms of student collaboration and multiple representations in the math classroom improved students' developmental math performance.

While the effects of these reforms are generally positive, most do not extend beyond improving students' math course performance. Moving forward, postsecondary math interventions and reforms may need to be more connected and comprehensive to have an enduring impact on students' college success.

Contents

Introduction

A major challenge facing students today as they pursue a postsecondary degree is a lack of academic preparedness for college-level math, evidenced by high rates of referral to developmental math and low rates of college math completion, particularly at 2-year colleges. Examining referral to developmental education by subject, Bailey, Jeong, and Cho (2010) found that 59 percent of incoming community college students are referred to developmental math compared to 33 percent to developmental English. Among students who started at a 2-year college in 2003, only 40 percent of students completed an introductory college math course and 9 percent completed an advanced math course as their highest math course after six years; the rest of the 2003 cohort completed only a developmental math course (21 percent) or no math course at all (30 percent) (Chen & Ho, 2012).

Beyond posing an obstacle to college math success, academic underpreparedness in math can have consequences for students' probability of completing college; interest and success in science, technology, engineering, and math (STEM) fields; labor market opportunities; and lifetime earnings (Baum, Ma, & Payea, 2010; Executive Office of the President, 2012; Jacobson & Mokher, 2009; Rivera-Batiz, 1992). Improving college math preparation is a critical, yet complex, endeavor that necessitates a multitude of reforms and interventions at both the secondary and postsecondary levels.

This research focuses on the interventions and reforms that postsecondary institutions currently employ to address academic underpreparedness in math and to foster college math success. The interventions and reforms fall under three strategies: (1) intervening prematriculation with early assessment programs, bridges, boot camps, and brush-ups; (2) reforming developmental math; and (3) improving math instruction. This brief synthesizes evidence from quasi-experimental designs (QEDs) and randomized controlled trials (RCTs).[1]

59 percent of incoming community college students are referred to developmental math compared to 33 percent to developmental English

1 *Descriptive research is not covered in this brief, but included in the full report. QED and RCT designs include a treatment group that received the intervention and a very similar comparison group of students who did not, so we know what would have happened if students did not experience the intervention. As a result, these designs allow us to understand the causal impact of the intervention on students' outcomes.*

For each strategy, the report describes typical interventions and reforms, provides some idea of the extent of their implementation across the country, and summarizes evidence of effectiveness. Table 1 shows the major findings on all outcomes across the reviewed studies.

- **Strategy 1** includes two studies: evaluations of the California Early Assessment Program (CA EAP; Howell, Kurlaender, & Grodsky, 2010) and the Texas Developmental Summer Bridge program (TX DSB; Barnett et al., 2012).
- **Strategy 2** includes five studies: evaluations of modularization (Boatman, 2012); learning communities (Weissman et al., 2011); shorter sequences/compression models (Edgecombe, Jaggars, Baker, & Bailey, 2013; Hodara & Jaggars, 2013); and mainstreaming (Boatman, 2012; Zeidenberg, Cho, & Jenkins, 2012).
- **Strategy 3** includes three studies: evaluations of student collaboration (Dees, 1991; DePree, 1998) and using multiple representations (Chappell, 2006).

Table 1. Findings of QED and RCT studies

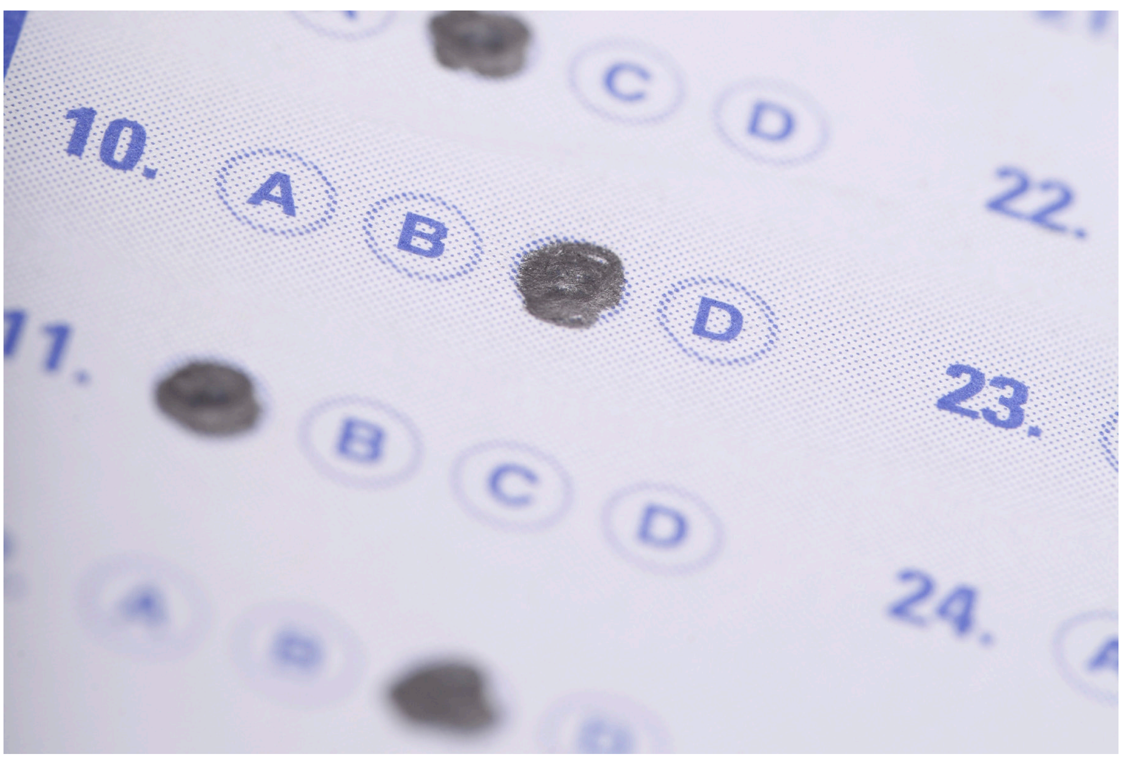
	OUTCOMES		
	Math Class Performance & Learning	**Credit Attainment & Persistence**	**Degree Completion**
Strategy 1 **Intervening Prematriculation**	• The TX DSB had a *short-term positive impact* on college math completion, but *no long-term impact* • The CA EAP had a positive impact on placement into college math, but the study *did not examine* course performance	• The TX DSB had *no impact* on credit attainment and persistence • The CA EAP study *did not examine* these outcomes	• Evaluations of prematriculation programs *did not examine* degree completion
Strategy 2 **Reforming Developmental Math**	• Shorter sequences had a *positive impact* on college math enrollment and completion • Learning communities had *a positive impact* on developmental math completion, but *no impact* on college math completion • Evaluations of modularization and mainstreaming *did not examine* these outcomes	• Shorter sequences and learning communities had *no impact* on these outcomes • Modularization had a *negative short-term impact* on persistence, but *no long-term impact* on these outcomes • Mainstreaming had a *positive impact* on credit attainment	• In one context, shorter sequences and mainstreaming had a *small positive impact* on degree completion • Evaluations of modularization and learning communities *did not examine* this outcome
Strategy 3 **Improving Math Instruction**	• Student collaboration and using multiple representations when problem-solving had a *positive impact* on performance in developmental math	• Instructional studies *did not examine* credit attainment and persistence	• Instructional studies *did not examine* degree completion

Source: Author's analysis.

Strategy 1

Intervening Prematriculation

Early assessment	Assessment offered to high school students to provide an early indication of their readiness for entry-level college English and math
Bridge programs	Summer programs that run for about a month designed to improve math skills, as well as orient students to college culture, provide nonacademic resources, and develop a network of support
Boot camps	One- to 2-week interventions offered prior to college entry designed to prepare students for the placement exam, but may also build college knowledge and provide nonacademic support
Brush-ups	Courses that last a few hours and focus on placement exam preparation



Early assessment, summer bridges, boot camps, and brush-up programs are offered prior to or during the matriculation process in an effort to help students avoid remediation once they enroll in college. These programs differ in duration, availability, and breadth of material covered. The evidence of the effectiveness of these programs is minimal, with only one QED of early assessment and one RCT of a summer bridge program.

Early assessment

Early assessment is a fairly widespread practice with 25 states supporting statewide early assessment programs; these states administer a statewide assessment that measures the readiness of high school students for all public 2-year and/or 4-year colleges (Barnett et al., 2012). Individual high schools in an additional 13 states implement their own early assessment programs. Only eight states also have statewide "transition curricula," which are English and math curricula offered in the senior year to students who do not test college-ready. In an additional 21 states, individual high schools, sometimes in partnership with local colleges, have developed their own transition curricula.

According to a study by Howell, Kurlaender, and Grodsky (2010), California's Early Assessment Program (EAP) had a positive impact on placement into college math. A central component of the program is optional items on the state standardized exam that assess students' readiness for college math and English at the California State University (CSU) system. High school juniors in the 2003 to 2004 academic years who completed the optional items were about four percentage points less likely to be referred to remedial math at CSU, Sacramento compared to their counterparts in the 2001 to 2002 academic years. The latter group of students did not complete the optional test items because EAP was not developed yet.[2] Howell and colleagues hypothesized that EAP participation lowered the likelihood of a remedial math placement as a college freshman because students who participated in EAP (by completing the optional test items) and tested into remediation were more likely to work on their math skills in high school than those who did not participate in the early assessment.

Programs that focus on improving placement test performance rather than math learning in general may not have a meaningful effect on students' long-term college success.

Bridges, boot camps, and brush-ups

According to recent, national scans, bridges and boot camps are relatively common at colleges across the country (Edgecombe, Cormier, Bickerstaff, & Barragan, 2013; Sherer & Grunow, 2010). Community colleges seem to be increasingly offering brush-up courses, which are low cost and easy to scale up (Hodara, Jaggars, & Karp, 2012).

A randomized experiment evaluated the effects of the Texas developmental summer bridge program offered to recent high school graduates at two open-admissions, 4-year colleges and six community colleges across the state in the summer of 2009 (Barnett et al., 2012). Although the programs at each college varied, they shared similar features: accelerated instruction in math, reading, and/or writing; academic support outside of class through individual tutoring; and a college knowledge component provided through a college success course or presentations and workshops. In addition, the programs offered an initial stipend of $150 to improve recruitment efforts and $250 after completion of the program to encourage students to finish.

After agreeing to take part in the study, participants were randomly assigned to the summer bridge treatment or the control group. A higher proportion of students in the treatment group than the control group passed a college-level math course through

2 Students who completed the optional English items were about six percentage points less likely to be referred to remedial English at CSU, Sacramento than their counterparts who did not (Howell et al., 2010).

fall 2010, but by spring 2011 there was no significant difference in the proportion of treatment group and control students who passed college math.[3] Also, there were no statistically significant differences between the two groups in the total semesters registered over the 2-year period and the number of college credits attempted and earned.

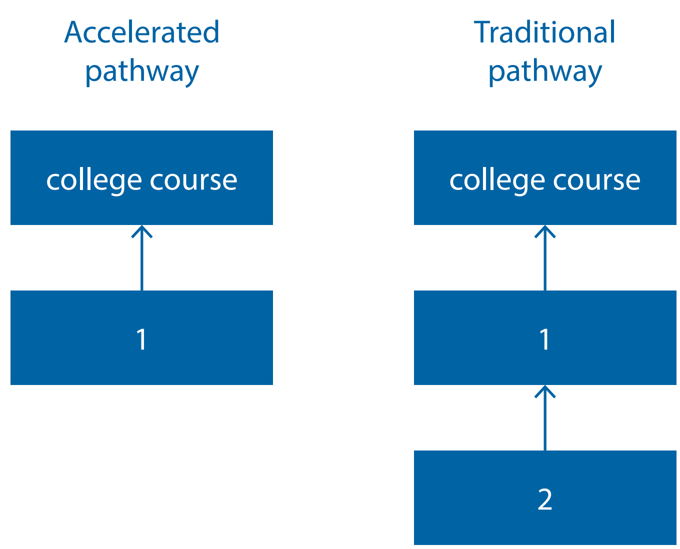
The researchers did not examine the program's impact on course placement after the intervention, which is the most common outcome across studies of early assessment, bridges, boot camps, and brush-ups. Instead, they focused on the longer term outcome of eventual college math completion. The statistically similar college math pass rates of the treatment and control groups signify that even if the Texas summer bridge program helped more treatment students place into college math, it had no long-term impact on helping them pass college math. This suggests that programs that focus on improving placement test performance rather than math learning in general may not have a meaningful effect on students' long-term college success.

3 *The same was true for treatment and control students referred to developmental reading: There were no significant differences in the proportion of students enrolling in college-level English.*

Strategy 2

Reforming Developmental Math

Learning communities	Students enroll together in two or more linked courses in the same semester creating a cohort experience
Modularization	Curriculum is divided into units or modules that cover specific math learning outcomes and students spend time only on those competencies that they have not mastered
Compression	Shortening the developmental sequence by combining two or more sequential courses into a single course maintains or decreases the number of contact hours
Mainstreaming	Students who place into developmental education are allowed to enroll in college-level math and receive supplemental support



Another strategy is to reform developmental math in an effort to improve the outcomes of students who enroll in these courses. Typically, developmental math encompasses a sequence of courses that students are placed into based on their placement exam performance. Sequences range in length, and some colleges may require more remedial math for students entering a STEM field compared to a liberal arts field. In a three-course sequence, for example, the lowest math course might cover arithmetic; the next course introductory algebra concepts; and the highest level course intermediate algebra, intended to prepare students for their first college-level math course, often college algebra or statistics.

Yet, the majority of developmental math students never complete their remedial requirements: some due to course failure and others because they simply do not enroll in the next course in the sequence (Bailey et al., 2010). High rates of course failure and student attrition may be due to the long sequence structure and misalignment between developmental and college-level standards and curriculum (Jaggars & Hodara, 2013). Reforms to developmental math attempt to shorten the sequence and/or align developmental and college math curricula to include the skills students need to be successful in the first college math course in their degree program. This review uncovered one RCT and five QEDs on various reforms to developmental math, which include learning communities, modularization, compression, and mainstreaming.

Learning communities

In a learning community, groups of students enroll in the same courses in the same semester in order to create a supportive network of peers, shared learning experiences, and deeper connections to college (Tinto, 1997). The learning communities demonstration was an RCT carried out at six community colleges across the country: four of the colleges linked a developmental English course with one or more courses, and two of the colleges, Houston Community College and Queensborough Community College, linked a developmental math course with a college-level or student success course (Weissman et al., 2011). At both colleges, the RCT found that the learning communities positively impacted students' developmental math pass rates, but did not have an impact on any other outcomes.[4]

Modularization

Modularization is a popular reform in developmental math, and one study (Boatman, 2012) allows us to understand the causal impact of modularization at two colleges in Tennessee. Cleveland State Community College and Jackson State Community College redesigned developmental math in 2007 by dividing their developmental math curriculum into 12 modules. Students move from one module to the next at their own pace, using computer-mediated instruction. Students place into developmental education based on their ACT scores in Tennessee, so Boatman (2012) employed a regression discontinuity design to identify the effects of modularization by comparing the outcomes of similar students who scored right above and below the ACT cutoff prior to the redesign and under the redesign.

At Cleveland State prior to the redesign, students in developmental math were 15 percentage points more likely to persist in college to the second semester than their counterparts in college math. After the courses were modularized, however, developmental math students were 21 percentage points less likely to persist than college math students. This negative effect is perhaps due to the nature of computer-mediated courses rather than the modularization of the curriculum: Less direct instructor guidance, difficulties with software, and/or a lack of structure may be related to lower persistence (Jaggars, 2012). After two years, the modularization of developmental math had no impact on student outcomes at both colleges, meaning students would have performed the same under the traditional sequence structure.

4 *While the math learning communities had a limited impact, the same RCT found that a learning community model at Kingsborough Community College had a long-term impact on students' eventual degree attainment (Weissmann et al., 2011). The learning community developed a strong connection between an English course (either developmental or college-level) and an orientation course and academic course, suggesting that the impact of learning communities may depend on the degree of curricular integration of the linked courses, the strength of the cohort model (i.e., students were in three courses together), and provision of nonacademic supports and college knowledge content.*

Compression

Compression is another popular developmental math reform (Edgecombe, Cormier, et al., 2013). Hodara and Jaggars (2013) did not examine a compression reform, but rather exploited a natural experiment in which community colleges in the City University of New York have the same standards of college readiness but different-length sequences. That means that similar students are subject to longer or shorter sequences depending on where they attend college. The researchers compared the outcomes of similar students who started in the lowest level of the three-course and two-course non-STEM math sequences.

Among the matched sample of students, students who started in a shorter non-STEM math sequence were 3.5 percentage points more likely to enroll in and 3 percentage points more likely to pass college math than their counterparts who started in the longer sequence. Starting in a shorter sequence had no impact, however, on 3-year college credit accrual and only a small positive impact on credential completion. Those who started in a shorter sequence were one percentage point more likely to earn an associate degree over three years compared to their counterparts.

The Community College of Denver (CCD) began to offer compressed versions of developmental courses in 2005, calling the program FastStart@CCD (Edgecombe, Jaggars, et al., 2013). FastStart@CCD encompasses a variety of course combinations but typically combines two sequential courses that would take two semesters to complete into one, single-semester course that maintains the same amount of contact hours. In addition to this change in course structure, Edgecombe, Jaggars, et al. (2013) found that faculty changed the math curriculum under FastStart to include more in-depth instruction on certain math topics and their pedagogy in order to keep students engaged over longer stretches of course time. For example, rather than lecturing the entire time, math instructors integrated more group activities into their classes. Another component of FastStart is that each participating student receives case management, which includes academic, career, and personal advising.

The researchers found that, controlling for a wide range of student-level characteristics, there was no difference in the semester-to-semester persistence, 3-year persistence, credits passed, and college credits passed among FastStart and non-FastStart developmental math students. FastStart did have a positive impact on students' passing the highest developmental math course and enrolling in and passing college math.

Mainstreaming

Mainstreaming, in which students who place into developmental math take college math and receive supplemental supports, is much less common than other developmental math reforms (Edgecombe, 2011; Edgecombe, Jaggars, et al., 2013). It is also more typically seen in English than in math courses.

Boatman's (2012) work in Tennessee also evaluated the effects of mainstreaming at the 4-year Austin-Peay State University, which eliminated its two developmental math courses and instead offered enhanced versions of two college-level math courses for students who placed into developmental math based on their ACT scores. The college math courses were linked to a structured learning assistance course or small-group tutoring workshops that covered material students were struggling with in the regular course. Boatman (2012) found no difference in the outcomes of students who barely placed into developmental math (i.e., ACT scores very near the cutoff) who enrolled in the new college math sections and students who barely placed into college math. This finding is quite promising because it means that students who were traditionally placed in developmental math can do just as well as their college math counterparts when they enroll in college math sections specifically designed with their needs in mind and receive tutoring supports. Results were even more positive when Boatman (2012) compared the effects on students assigned to developmental math at Austin-Peay pre- and post-redesign. Students who barely placed into developmental math but enrolled in the new college math courses passed more credits over two years and were more likely to persist from their first to second semester when compared to students who barely placed into developmental math before mainstreaming.

A second form of mainstreaming is integrating basic skills instruction into college-level courses (Perin, 2011). The Washington State Board for Community and Technical Colleges (SBCTC) developed the I-BEST model, intended to accelerate students' progress through the coursework required in their occupational certificate or associate degree program (Zeidenberg et al., 2010). In the I-BEST model, a basic skills instructor and an occupational instructor team-teach a college-level occupational or career-technical education (CTE) course and are in the classroom together for at least 50 percent of the instructional time (Wachen, Jenkins, Belfield, & Van Noy, 2012).

In their evaluation of I-BEST, Zeidenberg et al. (2010) found that basic skills students in occupational programs at schools where I-BEST was offered were 7.5 percentage points more likely to earn a certificate within three years (but no more likely to earn an associate degree) compared to similar students at colleges without I-BEST. They were also almost 10 percentage points more likely to earn some college credits. It is important to recognize, however, that because I-BEST involves the integration of both math and English basic skills, the results of the evaluation cannot be attributed to integrating math into the curriculum alone.

Strategy 3

Improving Math Instruction

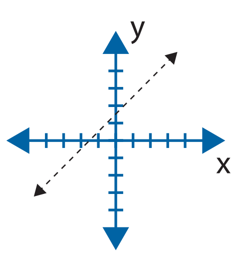
Structured student collaboration	Students work together in groups with formal roles and responsibilities to solve math problems
Using multiple representations	Classroom instruction teaches students to symbolize and solve math problems with formulas, graphs, symbols, and other representations

multiple representations

equation

$y = x + 2$

graph



table

x	y
-2	0
-1	1
0	2
1	3
2	4
–	–
–	–
–	–

words

x and y have a difference of two

x is two less than y

y is two more than x

There are no national studies that document the common features of math instruction in developmental and college math courses. Based on qualitative studies, however, typical developmental math pedagogy is thought to rely largely on procedural skill-building (Goldrick-Rab, 2007; Hammerman & Goldberg, 2003). For example, observational studies at 13 community colleges in California (Grubb, 2013; Grubb & Worthen, 1999) found that mathematics instruction was characterized by "remedial pedagogy"(i.e., review, lecture, independent seat work, and math problems devoid of application to the real world). Traditional features of math instruction that emphasize procedural skills have been linked to better performance on standardized tests, and much of the math that people encounter in their lives requires the ability to use algorithms to quickly and accurately solve computations. However, in order to truly understand mathematics, students need much more than procedural fluency (Hiebert & Grouws, 2007; Kilpatrick, Swafford, & Findell, 2001).

Therefore, an important component of improving students' college math readiness is improving math instruction in both the developmental and college-level classroom in order to support math learning and success. This strategy overlaps in some ways with Strategy 2 in this report, given that some reforms of the developmental math sequence structure and curriculum may result in changes to instruction or explicitly include instructional reform. However, this strategy focuses exclusively on changes to pedagogy inside the math classroom.

The larger report (http://capseecenter.org/publications/capsee-publications/) includes 28 studies on math instruction, but most of the reviewed studies did not employ a strong enough design to attribute differences in outcomes between the treatment and control groups to the instructional strategy. Specifically, studies on using metacognitive strategies and contextualization generally find positive impacts, but have methodological drawbacks that call into question the validity of their findings. Studies on computer-mediated instruction have a wide range of results from negative to positive, as well as methodological issues that make it difficult to draw conclusions from this research. The three highest quality studies on improving math instruction found positive effects of employing structured forms of student collaboration and using multiple representations to teach mathematics.

Structured student collaboration

Many instructors use cooperative learning in informal ways, but theory and research suggest that cooperative learning may not be effective unless it is formally and systematically integrated into a course. For example, a structured cooperative learning model is characterized by face-to-face interaction, personal responsibility in working toward a shared goal, the use of interpersonal skills, and group processing through the exchange of feedback, explanations, and other information (Johnson, Johnson, & Smith, 1991). In cooperative learning situations with these elements, students may experience increased motivation, better attitudes about math, and opportunities to talk out loud about problem-solving that lead to improvements in learning outcomes.

Two studies used cooperative learning models in the developmental math classroom with the above described elements and found they led to improvements in students' math performance. In a study by DePree (1998), students selected one of 50 sections of a developmental prealgebra course, unaware that seven sections would use small-group instruction and that six sections would be included in a control group using the traditional lecture mode of instruction. In the cooperative learning sections, a significantly higher percentage of students completed the course than in the control sections, and female and Latino students in the experimental sections reported significantly greater confidence in their mathematical ability than those in the control sections.

Dees (1991) randomly placed more than 70 students in her developmental math course into four laboratory sections taught by graduate assistants: Two used structured, small-group instruction and two used teacher-directed instruction with no group work. Students in the cooperative learning lab consistently outperformed students in the control group on measures of math achievement that included teacher-made tests and a standardized final exam.

Using multiple representations

Higher levels of math, such as algebra, require an understanding of how algebraic (or symbolic) representations can be depicted in graphs and in other forms. In addition, problem representation skills reflect a deeper understanding of math concepts (Brenner et al., 1997; Zawaiza & Gerber, 1993).

Chappell (2006) studied the impact of concept-based instruction, which uses multiple representations to teach math, in college calculus. In the concept-based sections, faculty taught students how to solve problems using numerical, graphical, and algebraic methods while constantly connecting new ideas to prior knowledge. In the control sections, faculty moved through the textbook, teaching definitions and formulas in a linear manner. Students in the concept-based sections performed significantly better on the midterm and final exams and were better able to transfer their understanding to unfamiliar concepts. For example, on a final exam problem that had never been introduced in any of the classes, 88 percent of the students in the concept-based classrooms answered this question correctly, representing their answer in different ways. Only 3 percent did not support their answer with an explanation. In the traditional sections, only 54 percent of the students answered this question correctly, with most providing a single formula to explain their answer and 31 percent not providing any explanation.

Conclusion

Presently, the evidence on postsecondary math interventions and reforms is limited and suggests that many of these interventions appear promising, but have a short-term positive impact on students' developmental or college math enrollment and/or course performance. An overall lesson of this review is that interventions aimed at improving students' math readiness may need to be more connected and comprehensive to have an enduring impact on students' educational outcomes.

In view of the studies examined in this report, secondary and postsecondary school leaders and educators working to improve students' college math readiness and success may want to consider the following recommendations:

1 Connect prematriculation programs to a larger framework of supports for high school students underprepared for college-level math.

Prematriculation programs tend to focus on preparation for a college placement exam and, perhaps as a result, current research finds their effect may be limited to decreasing remediation rates. In a more comprehensive approach, high schools would offer students early assessments to test their college readiness in their junior year and, just as critically, provide transition curricula in the senior year to students who do not test college-ready. For students who continue to struggle in math, colleges would offer summer bridges and boot camps that address gaps in students' math skills and understanding, as well as build their college knowledge and connect them to campus life and a network of support.

The Common Core State Standards (CCSS) provide an opportunity for public secondary and postsecondary systems to offer a connected set of supports for high school students transitioning to college. In the 2014–15 academic year, 45 states that have adopted the standards will administer new assessments aligned with the CCSS to juniors and the states will set a minimum cutoff score to be considered college- and career-ready (Barnett & Fay, 2013). For students who score below the cutoff, high schools and colleges have the opportunity to work together to develop transition curricula and prematriculation summer programs for students deemed underprepared for college math.

2 Design developmental math reforms that also attend to students' nonacademic needs.

This review found that shortening the developmental math sequence is a straightforward way to accelerate students' progress through developmental math and improve their college math enrollment and performance. The reforms that had a more substantial, long-term impact on students—in particular the mainstreaming models—also focused on students' nonacademic needs and provided targeted academic supports. For example, in most I-BEST programs, a mainstreaming model that improved students' certificate attainment, students received financial aid, case management, and tutoring support (Wachen et al., 2012).

Additionally, this review did not cover prestatistics pathways because rigorous research has not been conducted on this newer reform. But, this reform may represent an important direction for developmental math because in addition to shortening the sequence and aligning the curriculum to introductory statistics, it attends to psychological factors that affect math learning (Silva & White, 2013). Specifically, the courses integrate strategies that foster "productive persistence" in order to change students' mind-sets and teach them that struggle is a part of learning and not a sign of failure. The courses seek to improve students' work habits and encourage them to embrace challenging math.

3 Integrate effective math pedagogy into all interventions intended to improve students' college math readiness.

While more comprehensive reforms are needed, this review also found that instruction matters: Even small changes to pedagogy by math educators can make a significant impact on students' math learning. For example, in the study by Dees (1991), the instructional intervention involved a relatively small change. In the small-group instruction sections, individuals were placed in groups of four to six students and each received only part of the instructions to a problem. Students then shared their instructions with their group, and the group had to work together to understand the instructions and solve the problem. At the end of the activity, one group member was randomly chosen to explain the group's solution and the group's grade was based on this explanation, so group members had to collaborate to ensure everyone understood the solution steps and final answer.

Small-group instruction activities like these and/or using multiple representations when solving math problems can be integrated into summer bridge programs, boot camps, brush-ups, and developmental and college math courses, regardless of the course structure and curriculum.

These recommendations broaden the reach and scope of math interventions, requiring partnerships between high schools and colleges and the collaboration of faculty and staff from different departments and offices within the same college. While demanding greater effort, collaborative efforts to improve students' college math readiness may have a significant and lasting impact on students' math learning and overall college success.

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