The University of Texas at Austin
Charles A. Dana Center

The Case for Mathematics Pathways

A working knowledge of basic mathematics empowers individuals to engage productively in today's society and economy, which is increasingly reliant on data and quantitative reasoning. Yet all too often, mathematics is an obstacle rather than an opportunity to students who want to achieve their career goals through higher education.

A large body of evidence identifies traditional postsecondary mathematics as a primary barrier to degree completion and equitable outcomes for students (U.S. Department of Education, 2017). Traditional entry-level college mathematics programs fail to serve students well because they comprise disconnected courses whose content is misaligned to students' career and life needs. Underprepared students are especially impacted by multi-semester course sequences. These long sequences under-estimate the capability of students to learn mathematics and delay students' engagement with college-level coursework required for their degree programs. The impact of these course sequences is compounded by placement practices that often under-place students, especially students of color.

This brief presents the case that high-quality *mathematics pathways* can significantly increase student success by addressing three structural barriers of the problem: 1) the inaccurate placement of students, mostly into math courses below their ability to perform, 2) the misalignment of content to student needs, and 3) long, multi-semester course sequences. The Dana Center advocates for mathematics pathways that align to a student's academic and career goals and that accelerate student completion of a gateway college-level math course.

Figure 1. Structural Barriers in Traditional Mathematics Programs That Hinder Student Success

What are mathematics pathways?

Mathematics pathways enable students to take different paths through the math curriculum, making the math students learn relevant to their programs of study and careers. Model pathways vary but often focus on statistics, quantitative reasoning, or algebra/calculus.

What is the Dana Center?

The Charles A. Dana Center at The University of Texas at Austin is committed to promoting equity and access to quality math and science education for all students. Through the Dana Center Mathematics Pathways (DCMP) initiative, we help colleges, universities, and systems create course structures and rigorous learning environments that lead students to timely certificate or degree completion. To learn more, visit **www.dcmathpathways.org**.

Problem: Mathematics is an obstacle to degree completion and equitable outcomes for millions of students.

Traditional mathematics courses have been found to be the most significant barrier to degree completion for all fields of study (Saxe & Braddy, 2015). Each year in the United States, only 50 percent of students pass College Algebra, the most commonly enrolled college-level math course, and fewer than 10 percent of students who pass this course enroll in Calculus, the gateway to STEM degrees (Gordon, 2008).

Many students never make it to college-level courses. Nationally, an estimated 60 percent of incoming two-year college students are placed into at least one developmental math course each year. Unfortunately, only 33 percent of those students complete the developmental math sequence and 20 percent complete a college-level math course over three years (Bailey, Jeong, & Cho, 2010).

This issue impacts four-year institutions as well as community colleges. One-third of students in public four-year colleges take at least one remedial math course (Radford et al., 2012). Other research reveals that public four-year students who enroll in any remedial course (math or English) have a 55-percent, six-year graduation rate compared to 71 percent for those who do not (Ganga, Mazzareillo, & Edgecombe, 2018).

Outcomes are especially troubling for minority and underserved students. These populations are vastly overrepresented in remedial math courses and are consequently disproportionately impacted by the high rates of failure (EdSource, 2012). In 2012, only 55 percent of California's higher education students passed math courses that counted toward their degrees. Worse yet, a demographic breakdown found success rates of only 49 percent for Hispanic and 41 percent for African American students as compared to 60 percent for white students.

> **"High failure rates are not due to students or faculty. The problem lies in how mathematics programs are structured."**

While these data are discouraging, recent data from mathematics pathways implementation efforts provide clear evidence that the main drivers of high failure rates are *not* the capabilities of the students themselves. Nor are they reflections of the commitment and skill of those teaching and supporting students in developmental and gateway math courses. Rather, the reasons behind high failure rates lie in how mathematics programs are structured.[1] Below we describe three structural barriers of the problems and offer key recommendations to dramatically improve student success.

Barrier 1: Too many students are placed into developmental mathematics courses that they do not need.

Traditional placement policies, based on high stakes tests and standardized cut scores, place 60 percent of community college students and 40 percent of four-year students into non-credit bearing developmental mathematics (Ganga et al., 2018). Research shows that the use of a single test for placement systematically underestimates students' ability to succeed in college-level courses. Scott-Clayton (2012) estimates that one in four students placed into developmental mathematics could pass a college-level mathematics course with a B or better. There is also a mismatch between algebra-focused tests and the preparation actually necessary for non-algebraically intensive courses such as Statistics and Quantitative Reasoning. Equity concerns are also evident as research consistently shows that traditional placement models disproportionately impact students of color and low-income students (Bailey et al., 2010; Barnett & Reddy, 2017).

Placing students into remedial coursework that they do not need has serious consequences. Layers of standalone remediation lengthen the time to degree completion, increase costs, and contribute to high rates of attrition (Ganga et al., 2018).

Instead, to maximize access, equity, and completion of a gateway course, colleges should assess readiness through multiple measures that gauge likelihood of success in the student's chosen pathway. High school grade point average, for example, is a robust reflection of a student's performance over time, across subject areas, and in varying instructional settings (Hodara & Cox, 2016). If placement tests are used as part of a multiple measures strategy, the content assessed should be aligned to the content of the mathematics course and ranges should be used rather than cut scores.

EVIDENCE THAT BETTER PLACEMENT POLICIES SUPPORT MATH PATHWAYS

Many studies show that students placed under multiple measures have better outcomes. During the initial two years that Davidson County Community College used multiple measures, 65 percent of students placed using high school transcript data successfully completed a gateway math course compared to 48 percent of students who were placed using a placement or standardized test (Center for Community College Student Engagement, 2016).

Early findings from a randomized controlled trial underway within the State University of New York System show that placement using multiple measures improved completion of college-level math courses by three percentage points (and more than 12 points in English) and narrowed the gender gap between men and women (Barnett et al., 2018).

Cuyamaca College implemented multiple measures placement along with math pathways that included co-requisite support. The college saw dramatic positive results that included jumps in gateway math completion from 15 percent to 65 percent for Latinx students, 6 percent to 55 percent for African American students, and 16 percent to 76 percent for white students (California Acceleration Project, 2017).

While using multiple measures to place students improves accuracy of placement into college-level courses, there is still some percentage of students who will be identified as underprepared. Many of those students are capable of success in a college-level course if additional supports are provided. This co-requisite approach, which will be discussed later in this brief, is increasingly prevalent and fits well with mathematics pathways because students enroll directly into gateway courses aligned with their intended programs and academic interests.

High failure rates lie in how math programs are structured.

1. Too many students are placed into developmental mathematics courses that they do not need.
2. Traditional entry-level math programs are not aligned with students' mathematical needs.
3. Long developmental course sequences decrease students' chances of completing a credit-bearing mathematics course.

Barrier #2: Traditional entry-level math programs are not aligned with students' mathematical needs.

For decades, College Algebra has been the dominant gateway mathematics course in higher education. In Fall 2010, 54 percent of four-year college students and 80 percent of two-year college students were enrolled in entry-level (e.g., College Algebra) or precollege algebraically intensive mathematics coursework (Blair, Kirkman, & Maxwell, 2013).

The appropriate pathway is based on a student's goals, not preparation.

It is a misconception that better prepared students should take College Algebra and underprepared students should take other pathways. Further, the content of any pre-requisites or co-requisites should align to the gateway course.

College Algebra was originally intended to prepare students for Calculus. Over time, however, College Algebra became the default mathematics experience for most students, but at most institutions, less than 20 percent of students in College Algebra are in programs requiring a yearlong calculus sequence (Herriot & Dunbar, 2009). In 2004, the Mathematical Association of America (MAA) called for the end of using College Algebra as a terminal mathematics course, citing this serious mismatch between the original rationale for College Algebra and the mathematical needs of students who take the course (MAA, 2004).

In 2015, the MAA, along with four major mathematical professional associations—the American Mathematical Association of Two-Year Colleges (AMATYC), the American Mathematical Society (AMS), the American Statistical Association (ASA), and the Society for Industrial and Applied Mathematics (SIAM)—reaffirmed this recommendation, calling for multiple mathematics pathways that are aligned to fields of study, some of which should include early exposure to statistics, modeling, and computation (Saxe & Braddy, 2015).

Even in institutions that offer multiple options for entry-level mathematics courses, the prevailing practice is often to advise the majority of students into College Algebra. However, as is discussed below, all students benefit from and should have the opportunity to learn mathematics that is relevant to their academic interests and goals regardless of their preparation.

Two concerns drive the persistence of using College Algebra as the default gateway math course. Some educators worry non-Algebra pathways limit options for students who might later move to STEM. Data demonstrate that relatively few students change from non-STEM majors to STEM (Charles A. Dana Center, 2018b). Therefore, institutions should design math pathways to serve the needs of the greatest number of students possible, while ensuring that appropriate options exist for students who change to STEM majors.

Related resources can be found at dcmathpathways.org:

- *A Call to Action to Expand Access to Statistics* (2015)
- *Mathematics Pathways: Scaling and Sustaining* (2018a)
- *Prevalence of Students Changing to STEM Majors: Implications for Mathematics Pathways* (2018b)

A second concern is that courses other than College Algebra will either not transfer or will not apply to a student's degree at another institution. In order to succeed in converting math pathways to normative practice, it is critical to ensure that the transfer *and* applicability of the courses to degree plans are consistent and predictable. Consequently, a key strategy for implementing mathematics pathways is for mathematics departments to work with partner disciplines across institutions to align math pathways to the appropriate programs of study.

EVIDENCE THAT BETTER ALIGNED CONTENT IN MATH PATHWAYS HELPS STUDENTS

When students engage with mathematics relevant to their programs of study—for example, a statistics course for a social science major or a quantitative reasoning course with real-world mathematics in finance or citizenship for an English major—they are more motivated and more likely to succeed (Rutschow & Diamond, 2015). While there have not been any large-scale studies determining whether expanding options for gateway courses increases student success, there is emerging evidence that shows promise. In 2014, The University of Texas at Arlington began shifting enrollment out of College Algebra and into quantitative reasoning and statistic courses. The success rates increased in all three gateway courses.

Students enrolled in the New Mathways Project (NMP) statistics pathway experienced higher engagement and achieved higher grades and pass rates as compared to those enrolled in traditional algebraically intensive math courses. NMP students reported being "surprised by how relevant math could be to their lives and how they could more critically evaluate everyday quantitative information . . . . Many had started in the NMP classes feeling they could never grasp math, and many left . . . more confident in their ability to approach the quantitative issues that they face in their everyday lives" (Rutschow & Diamond, 2015, p. 53).

In addition, 56 percent of City University of New York (CUNY) students in a randomized controlled (RCT) study passed a college-level statistics course (with instructional support) compared to 45 percent who were randomly assigned to a developmental algebra course (also with support). The only difference between the two groups was the mathematics content; students with the same level of preparation received the same level of support from the same instructors (Logue & Watanabe-Rose, 2014).

Barrier #3: Long developmental course sequences decrease students' chances of completing a credit-bearing mathematics course.

Students who are not deemed college ready upon matriculation often have to enroll in long sequences of remedial coursework before they are allowed to enroll in a college-level math course. These multi-course sequences have been shown to present uneccessary barriers to student success over time.

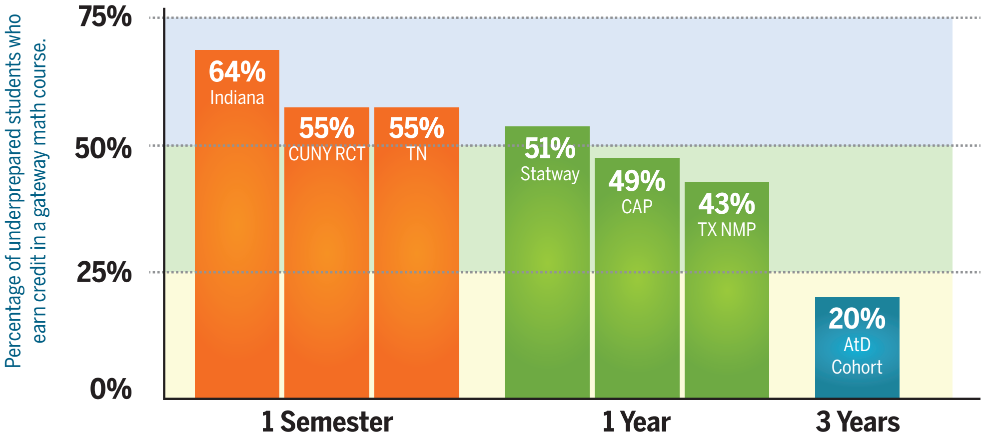
Numerous studies show that these long course sequences have high attrition rates (Bailey et al., 2010; Hern, 2010). Students' progression is complicated by several exit points at which students leave the sequence by not enrolling, not passing, and/or not persisting to their college-level math course. Bailey et al. (2010) examined data on more than 141,000 students enrolled in Achieving the Dream colleges over a four-year period; these students were referred to one to three developmental mathematics courses before taking college-level math. Only 10 percent of students who were referred to three courses of developmental mathematics and enrolled in a developmental course completed a college-level mathematics course in three years. The rate across all students enrolled in developmental mathematics was 20 percent; that is, over 113,000 students in this study did not proceed to college-level work.

These studies highlight a need to change how the success of our programs is evaluated. Rather than being satisfied with success in individual courses, we need to know whether students reach important milestones and complete meaningful requirements. Success rates in individual courses may be relatively high, but this metric obscures the effect of attrition between courses and the inevitable multiplicative attrition over a two- or three-course sequence.[2] By changing the metric to success in earning college-level credit and credential completion, the devastating effect of long course sequences on students is revealed.

EVIDENCE THAT SHORTER MATHEMATICS SEQUENCES HELP STUDENTS

While not the silver bullet for eliminating failure in postsecondary mathematics, there is mounting evidence that a large majority of students, including those who are referred to developmental mathematics, can succeed in accelerated college-level math courses with appropriate support.

Figure 2. A Preponderance of Evidence
More students succeed in less time with accelerated models



Consistent results across multiple sites using different models show that more students earn credit in less time with accelerated models.

Sources: Indiana (Complete College America, 2016); CUNY (Logue et al., 2016); Tennesse (Tennessee Board of Regents, 2016); Statway (Sowers & Yamada, 2015); CAP (California Acceleration Project, 2015); TX NMP (Rutschow & Diamond, 2015); and AtD (Bailey et al., 2010).

These efforts have generally fallen into two categories: one-year models and one-semester co-requisite models in which developmental students enroll directly into a college-level gateway course but receive additional instructional support through a supplemental, concurrent non-credit bearing course. The co-requisite model is quickly gaining prevalence as a way to reduce “stop-outs” associated with multi-term course sequences where even students who pass a course often do not enroll for the next one. Students respond well to co-requisite models because direct enrollment in college-level courses is more motivating and an appropriate college-level course is more relevant to their goals. The reduction in the time and cost to complete a credential is an added benefit.

Data clearly show that underprepared students can succeed in college-level math courses at higher rates *and* in less time as compared to students in traditional developmental sequences in both the one-year and one-semester models; however, the greatest improvement comes from one semester co-requisites (Bailey et al., 2010; California Acceleration Project, 2015; Complete College America, 2016; Logue, 2018; Rutschow & Diamond, 2015; Sowers & Yamada, 2015). For example, Tennessee implemented one-semester, co-requisite courses across all public two-year and four-year institutions. In the community colleges, 52 percent of underprepared students passed a gateway course with co-requisite supports in one semester compared to 12.3 percent in one year in the traditional pre-requisite model. Tennessee universities saw a jump from 58.9 percent completion in a year to 75 percent completion in one semester (Tennessee Board of Regents, 2016).

Increases in success is not limited to gateway course completion. CUNY tracked its co-requisite students in the RCT referenced above and found not only did more students complete their gateway math courses in less time, but also more students completed credentials, transferred, or remained enrolled after three years (Logue, 2018).

CONCLUSION

This brief makes the case that many more students will be successful in rigorous, challenging, and relevant courses that are part of well-designed mathematics pathways utilizing policies and structures that are informed by research and shaped by the practice guidelines of the major professional associations. Implementing math pathways requires institutional and state-level changes that place students appropriately, align students' mathematics courses to their programs of study, and allow students to enter into college-level courses quickly.[3] Making these three major structural changes will have a significant positive impact and will complement institutions' other student success strategies such as robust advising, guided pathways, and use of evidence-based curriculum and pedagogy.

The Dana Center makes the following recommendations:

1. A key success metric in evaluating math pathways is the percentage and number of students who earn credit in a college-level math course that is appropriately aligned to their programs of study and who complete a credential.
2. Placement practices should use multiple measures, align to the content of math pathways, and be based on evidence of effectiveness.
3. Students should enroll in math pathways that reflect their academic interests and intended programs of study—not their level of preparation.
4. Underprepared students should enter into accelerated pathways with a one-semester, co-requisite model as the default unless there is compelling evidence they will be more successful in another course structure.
5. There should be accelerated structures for all pathways including the algebraically intensive pathways leading to Calculus.

We hope this call to action will encourage mathematics educators and higher education administrators to seriously consider implementing multiple math pathways at their institutions. More information can be found at the DCMP resource site, www.dcmathpathways.org.

ENDNOTES

[1] See *Core Principles for Transforming Remediation within a Comprehensive Student Success Strategy* (2015).

[2] *Multiplicative attrition* refers to the attrition over a sequence of courses. For example, individual courses may have a success rate of 70 percent; after two courses, only 49 percent (.7 x .7 = .49) of the original cohort succeed; and after three courses, only 34 percent succeed.

[3] The Dana Center believes that most students should enter directly into a college-level math course with appropriate supports for underprepared students. Any other placement should be based on evidence that it will increase the student's chance of success. We recognize that some students may need more intensive instruction than can be provided in highly accelerated or intensified classes. Therefore, along with our partner organizations, we are calling for an initiative to address this issue in ways that allow us to responsibly serve *all* students seeking to improve their lives through higher education.

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About the Charles A. Dana Center at The University of Texas at Austin

The Dana Center develops and scales education innovations to support educators, administrators, and policymakers in creating seamless transitions throughout the K–14 system for all students, especially those who have historically been underserved. We focus in particular on strategies for improving student engagement, motivation, persistence, and achievement.

We help local systems adapt promising research to meet their needs, and we develop innovative resources and tools that are implemented through multiple channels, from the highly local and personal to the regional and national. We provide long-term technical assistance, collaborate with partners at all levels of the education system, and advise community colleges and states.

The Center was founded in 1991 at The University of Texas at Austin. Our staff members have expertise in leadership, literacy, research, program evaluation, mathematics and science education, policy and systemic reform, and services to high-need populations. We have worked with states and education systems throughout Texas and across the country. For more information about our programs and resources, see **www.utdanacenter.org**.

About the Dana Center Mathematics Pathways (DCMP)

The Dana Center Mathematics Pathways (DCMP) is a systemic approach to dramatically increasing the number of students who complete math coursework aligned with their chosen program of study and who successfully achieve their postsecondary goals. The DCMP was initially launched as the New Mathways Project (NMP) in 2012 through a joint enterprise with the Texas Association of Community Colleges. For more information about the DCMP, see **www.dcmathpathways.org**.

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