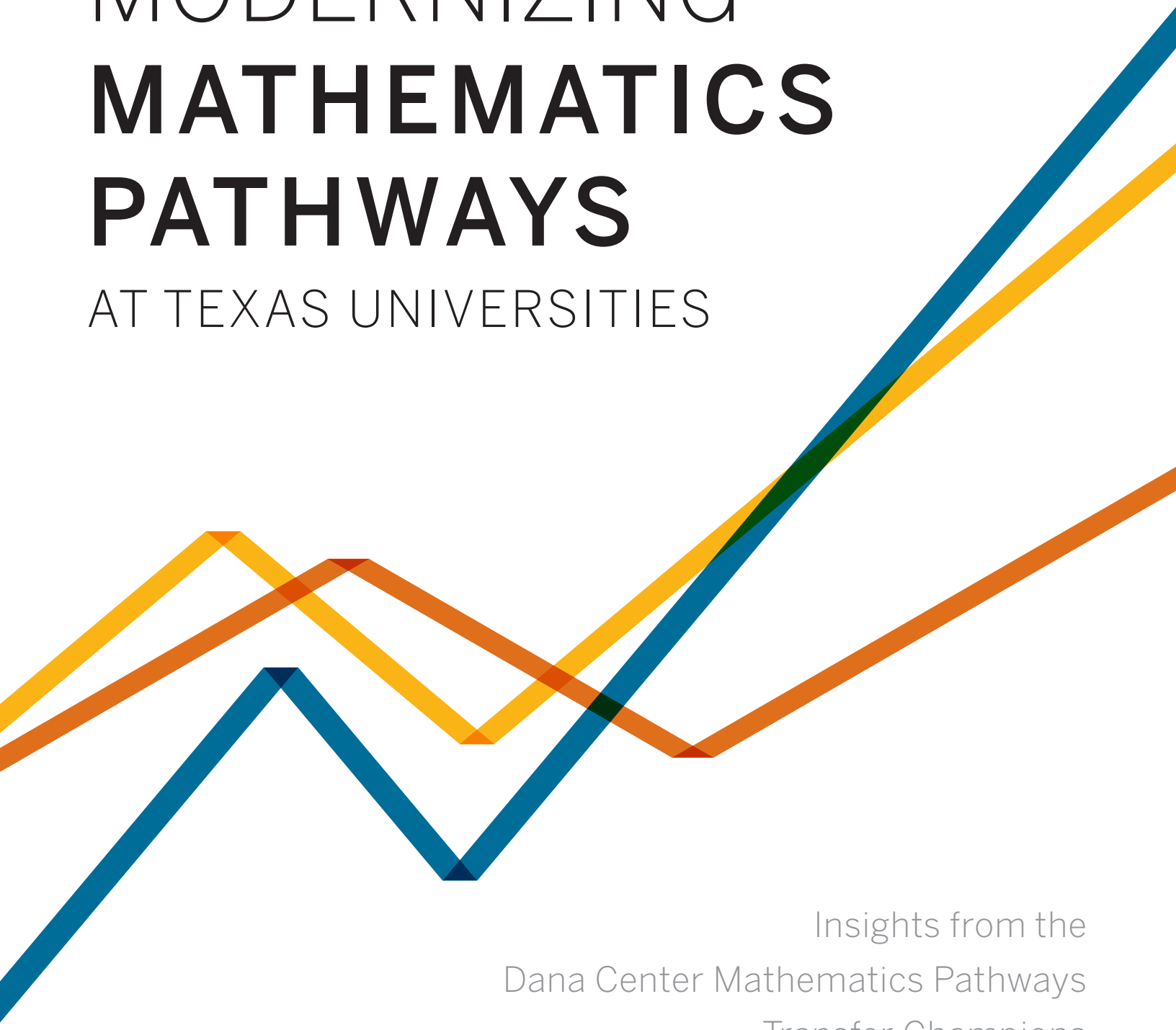
The Charles A. Dana Center
at The University of Texas at Austin

MODERNIZING **MATHEMATICS PATHWAYS** AT TEXAS UNIVERSITIES



Insights from the Dana Center Mathematics Pathways Transfer Champions

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ABOUT THE DANA CENTER MATHEMATICS PATHWAYS

The University of Texas at Austin
Charles A. Dana Center

THE DANA CENTER MATHEMATICS PATHWAYS model (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 Dana Center launched the Dana Center Mathematics Pathways model in 2012 through a joint enterprise with the Texas Association of Community Colleges.

The principles that define the DCMP model include:

1. Multiple pathways with relevant and challenging mathematics content aligned to specific fields of study
2. Acceleration that allows students to complete a college-level math course more quickly than in the traditional developmental math sequence
3. Intentional use of strategies to help students develop skills as learners
4. Curriculum design and pedagogy based on proven practice

This initiative is made possible through the generous support from the Carnegie Corporation of New York, Greater Texas Foundation, Houston Endowment, Kresge Foundation, Meadows Foundation, the State of Texas, and TG.

For more information about:

- the Dana Center Mathematics Pathways, see www.dcmathpathways.org
- the Texas Association of Community Colleges, see www.tacc.org

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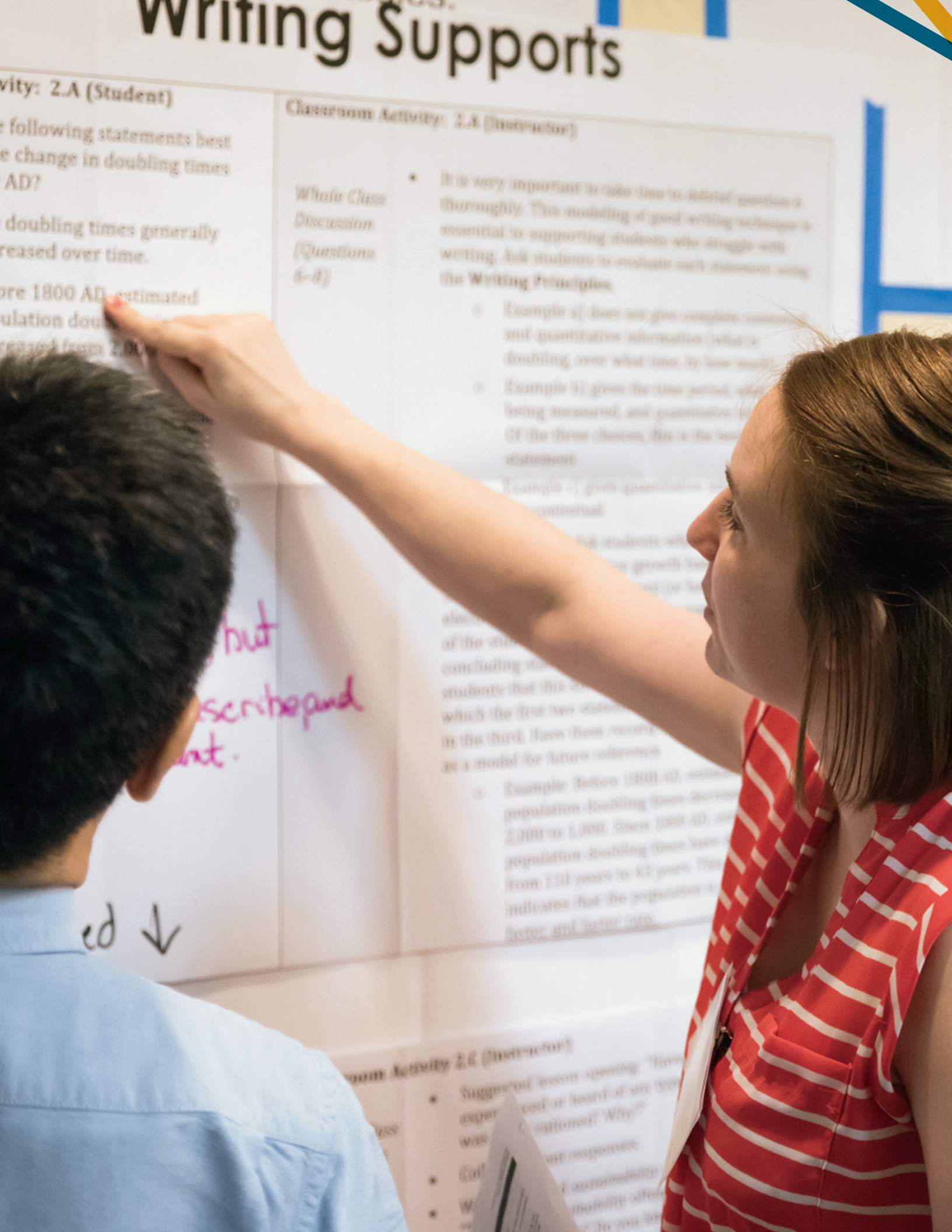
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EXECUTIVE SUMMARY

FOR DECADES, the traditional algebra- and calculus-based mathematics sequences were regarded as the best route for almost all two- and four-year students, regardless of their majors. Today, that is no longer the case. College mathematics requirements are changing in response to the evolving needs of students, the economy, and society at large. Enrollments in statistics and quantitative reasoning courses are on the rise, while enrollments in college algebra are declining on many campuses.

Texas is a national leader in developing multiple pathways that connect with students' programs of study. Many Texas universities already established modern mathematics pathways that are aligned to different programs of study: statistics for students in the social sciences and health fields; quantitative reasoning for students in the liberal arts and fine arts; and the calculus preparation sequence for students in STEM majors. This work parallels the efforts of the state's 50 community colleges that, through the Dana Center Mathematics Pathways, implement multiple mathematics pathways beginning at the developmental level.

This case study describes the evolution of multiple mathematics pathways and the change process of seven pioneering universities. The study aims to help other institutions in Texas and nationally that are planning to modernize their mathematics programs by offering multiple pathways. Informed by interviews with deans, department heads, and faculty representatives, we present implementation advice for other four-year institutions and their community college partners in ways that enhance system coherence and ease of student transfer. Key recommendations include:

- DEFINE THE PROBLEM so that the case for collective action is clear.
- ENGAGE FACULTY AND ADMINISTRATORS across math and other departments.
- INVOLVE ADVISORS so that students get the right messages.
- ENSURE NEW MATH PATHWAYS ARE TRANSFERABLE and specify math requirements for each major.
- SITUATE MATH PATHWAYS IN A BROADER REDESIGN of credential programs.
- COMMUNICATE REGULARLY WITH TRANSFER PARTNERS so they understand program requirements and know their university colleagues.
- COMPARE SCHOOL REQUIREMENTS AND POLICIES with those of other institutions in the state.

MAKING A CASE
FOR MODERNIZATION

A DECADE AGO, the University of North Texas (UNT) in Denton, Texas, launched a university-wide process to review the undergraduate curriculum and the courses that should make up UNT's core curriculum. Dr. William Cherry, a mathematics professor on the curriculum review committee, stood up during one meeting and declared, "We keep saying that algebra is critical to have in the core curriculum, but the mathematics faculty increasingly does not believe this to be the case. Although college algebra can be a critically important course for some STEM students who did not adequately master algebra in high school, it is the wrong core curriculum course for our students. In fact, it is wrong in every case."

For students in STEM majors, Cherry explained, pre-calculus and calculus are the most appropriate math courses, not college algebra. If these students have not mastered algebra, they are already behind. The higher level math courses in STEM degree plans should be the college math starting point for these students.

Cherry went on to explain that college algebra is not the best choice for non-STEM majors either. College algebra was never intended to be a terminal math course; unless followed by higher level courses, college algebra provides little "value added" beyond what students should have learned in high school Algebra II. Students would be better served, Cherry argued, if they learned the math they would actually use in their work lives. They would far more likely remember their college math if they are able to apply it.

For students majoring in programs such as social or behavioral sciences, the most important mathematics is statistics, not algebra. For liberal arts students, who typically need to take one core math course to graduate in their majors, quantitative reasoning is likely to be more relevant to their future lives and careers.

For the mathematics faculty at UNT, requiring college algebra in the core curriculum caused other problems. The faculty was concerned about anecdotal stories that high school guidance counselors were sometimes advising students interested in engineering and science careers to enroll in dual-credit college algebra to meet the core requirement, rather than to pursue pre-calculus or AP calculus, which would better serve them in STEM majors. Moreover, the use of college algebra as a general core curriculum course resulted in large enrollments in college algebra of students with a diverse set of interests and needs. Consequently, the faculty found it difficult to meet the varying needs of students in STEM majors and non-STEM majors in this "one-size-fits-all" class.

Students would be better served ... if they learned the math they would actually use in their work lives.

Cherry supported the mathematics department's bold recommendation that the committee drop college algebra as a core curriculum requirement. Students instead should be able to choose among one of several distinct, first college-level math courses aligned to their programs of study. The committee members' initial shock at Cherry's recommendation was eventually replaced by their approval. The core curriculum committee asked each department and major at UNT to identify a preferred core math requirement from among three different courses: Calculus (or pre-calculus); Elementary Probability and Statistics; and Survey of Mathematics with Applications (a quantitative

reasoning course). The College of Business and the College of Education argued that their students needed more customized courses, so both colleges worked with mathematics faculty to identify math courses that better suited their students' future careers. At the same time, UNT removed the word *college* from its college algebra course to emphasize that high school students intending to pursue a STEM degree at UNT should take a strong calculus preparation course in their senior year in order to be "calculus ready."

The University of North Texas implemented multiple pathways systematically across the institution, which created a ripple effect among transfer partners. Many community college advisors were indeed surprised after learning that UNT no longer required all transfer students to take college algebra. The university's Vice Provost for Transfer and Articulation Celia Williamson notes, "A discussion of 'what math fits' is part and parcel of our conversation as we develop program-to-program curricular alignments between specific community college programs and specific majors at UNT." The university, therefore, communicates expectations for mathematics coursework clearly and frequently to minimize confusion among their transfer partners.

The University of North Texas is one of seven pioneering institutions that recognized early on that the traditional, one-size-fits-all, algebra-based math sequence did not serve its students and faculty—or the state—particularly well. This case study highlights the experience of those four-year universities in Texas that, over the last decade, decided to build their own versions of multiple pathways in mathematics.

There is much to learn from the individual efforts of those institutions, including the factors that drove them to action, the obstacles and challenges they faced, and implementation advice they can offer to other higher education institutions. Their reforms demonstrate a trend among Texas universities toward redesigning undergraduate mathematics to align with the needs of students' programs of study and career plans—a trend with significant implications for community college transfer partners and the alignment of math pathways across institutions. //

TRANSFER CHAMPION UNIVERSITIES
WITH MODERN MATHEMATICS PATHWAYS

Stephen F. Austin State University

Texas Tech University

University of Houston–Downtown

University of North Texas

The University of Texas at Austin

The University of Texas–Pan American

The University of Texas at Tyler

THE NEW NORMAL:
MULTIPLE MATHEMATICS PATHWAYS

COLLEGE MATHEMATICS REQUIREMENTS are changing in response to the evolving needs of students, the economy, and society at large. For decades, the traditional algebra- and calculus-based mathematics sequences were regarded as the best route for almost all two- and four-year students, regardless of their majors. Today, that is no longer the case.

A recent survey of changes in college mathematics education shows a growing shift toward requiring more statistics-based mathematics.[1] According to the report, in some research universities, math courses for biology students emphasize statistics over traditional calculus-based courses, and a growing number of social science departments, such as psychology and political science, now requires statistics for either admission or graduation. Likewise, medical schools are changing their entrance requirements to emphasize a foundation in statistics, while other schools are enhancing their quantitative reasoning courses and sequences. For example, all community colleges in Indiana and Colorado are implementing a new quantitative literacy sequence to add to their standard algebra-based sequence.[2,3]

Given that nationally, only 20 percent of community college students and 28 percent of four-year students enroll in programs that require calculus, there is a growing consensus that additional (non-algebra-based) mathematics pathways are needed that are better aligned with students' programs of study.[4] Task forces in Georgia, Ohio, Missouri, and Nevada have concluded that college algebra should not be

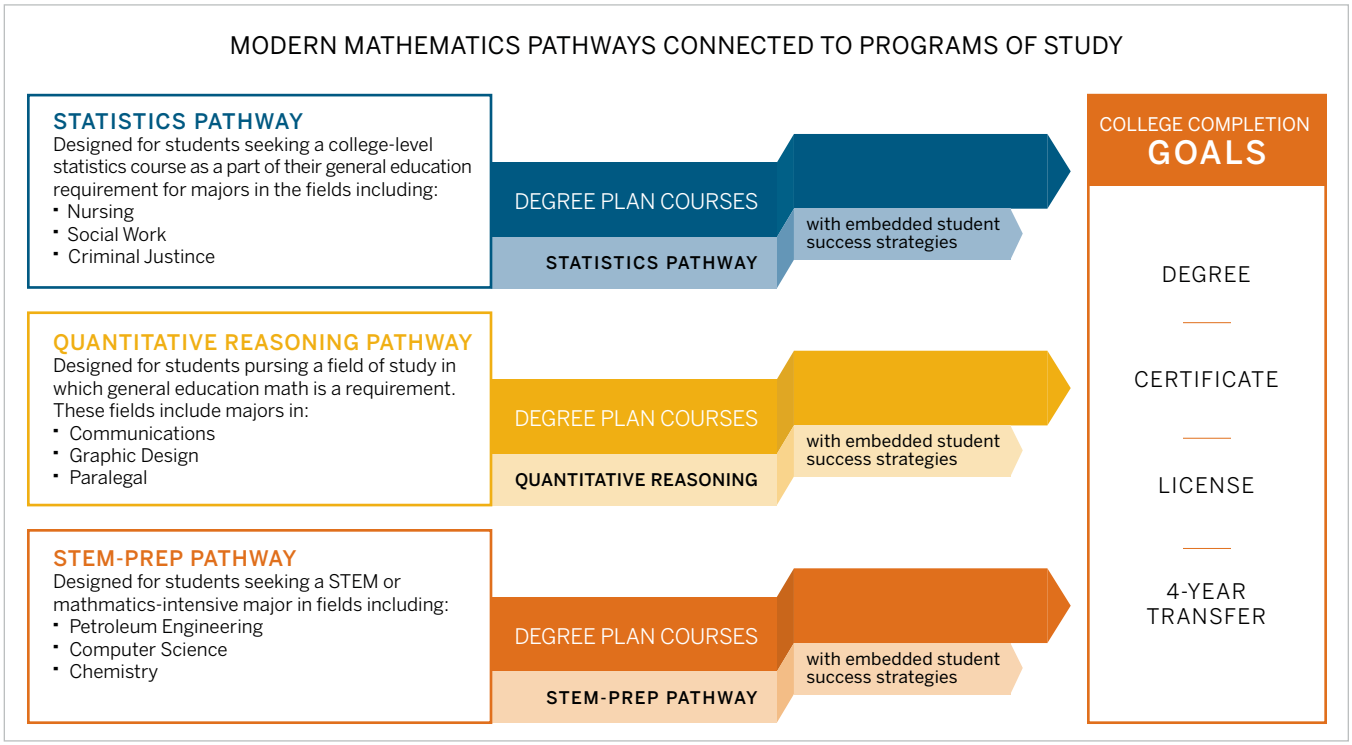

FIGURE 1

the default math requirement in fields not requiring calculus.[5,6,7,8] Multiple pathways are gradually becoming the "new normal" in higher education mathematics.[9]

Across the United States, a common version of multiple mathematics pathways is the addition of two pathways to the algebra-intensive, calculus-driven mathematics course sequence appropriate for STEM students: a statistics pathway for health and social science majors; and a quantitative reasoning pathway for liberal arts and fine arts majors (*see Figure 1*).* The effects are already being felt: Enrollments in statistics and quantitative reasoning courses are on the rise, while enrollments in college algebra are declining on many campuses.[10]

Texas is a national leader in developing multiple pathways that connect with students' programs of study. Since 2012, The Dana Center Mathematics Pathways (DCMP), a joint project of the Charles A. Dana Center at The University of Texas at Austin and the Texas Association of Community Colleges, has been working with the state's 50 community colleges to promote the implementation of mathematics pathways that enable students placed in developmental education to complete a credit-bearing, transferable mathematics course on an accelerated timeline. The DCMP's new approach helps underprepared college students to move more quickly to mathematics proficiency. The one-year pathways begin with remediation and end with completion of a first-year college math course. The DCMP model and course resources are designed to meet the learning outcomes of standard, transferable, first college-level math courses in each of three distinct mathematics pathways: statistics (in Texas, Elementary Statistical Methods, Math 1342/1442); quantitative reasoning (Contemporary Mathematics, Math 1332); and an algebra-based STEM-prep pathway designed to prepare students for calculus (College Algebra, Math 1314/1414, and Pre-Calculus, Math 2412).

The Texas Higher Education Coordinating Board implemented several policy changes that helped accelerate adoption of multiple mathematics pathways. Development of common course learning outcomes and the specification of a 42-hour, transferable core curriculum clarified what content should be covered in first college-level math courses and which mathematics courses can be included in a Texas-wide

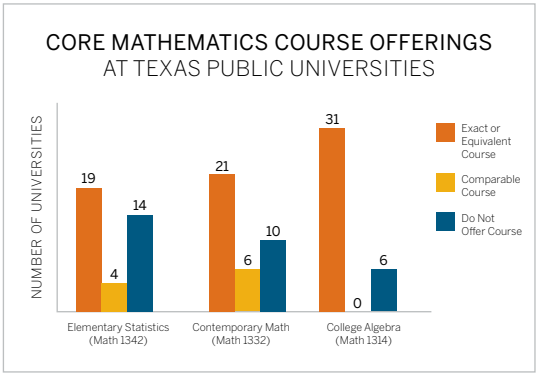

FIGURE 2

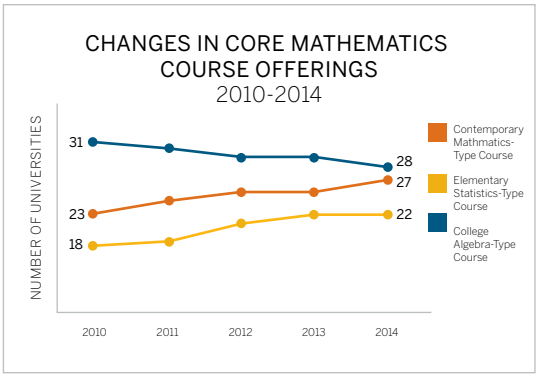

FIGURE 3

core curriculum. As a result, course and credit transferability from community colleges to four-year institutions became clearer and more routine.

The progress made by Texas colleges and universities in revising mathematics courses to include non-algebraically intensive pathways was evident in a 2014 Coordinating Board rule under the new Texas Success Initiative (TSI), which clarifies how developmental education students can demonstrate completion of their TSI readiness requirements. The rule allows institutions to use either of two college readiness ("TSI-complete") designations in mathematics—one for students in any freshman-level mathematics course and another for students who are college ready for non-algebraically intensive mathematics courses only. The latter category includes statistics and quantitative reasoning (known in Texas as contemporary mathematics).

According to Dana Center research, among 37 public four-year institutions across Texas, 31 schools offered either statistics or quantitative reasoning courses as eligible core mathematics courses in 2014 (*see Figure 2*).[11] Many of these institutions offered both courses. Since 2010, ten institutions have added statistics or quantitative reasoning courses—or both—to their core curricula (*see Figure 3*). //

*There are a number of variants to this model. In Texas and elsewhere, business mathematics is often a separate pathway. It is algebra-based but tailored to address common business applications. Education programs often have their own mathematics requirements, given the interest in preparing future teachers to teach a range of math courses.

LEARNING FROM
THE PIONEERING TRANSFER CHAMPIONS

THE MULTIPLE MATHEMATICS TREND parallels the work of Texas community colleges through the Dana Center Mathematics Pathways. In 2013, the Dana Center Mathematics Pathways launched an initiative to leverage the experience of "early adopters" of multiple mathematics pathways in Texas and to lend support for this approach among the state's community colleges. DCMP's Transfer Champions Initiative fosters regional collaboration among universities and community colleges in order to facilitate the implementation and alignment of multiple mathematics pathways as they develop across institutions.

Of the 17 institutions invited to participate in the first year, seven of those universities had already established modern mathematics pathways that were aligned to different programs of study: statistics for students in the social sciences and health fields; quantitative reasoning for students in the liberal arts and fine arts; and the calculus preparation sequence for students in STEM majors. At each of these universities, requirements for four high-enrollment majors—nursing, communications, criminal justice, and social work—were aligned with the recommendations from mathematics and discipline professional associations that mathematics course sequences for those programs be non-algebraically intensive.*

This case study aims to help other institutions in Texas and nationally that are planning to modernize their mathematics programs by offering multiple pathways. Informed by interviews with deans, department heads, and faculty representatives from the seven Transfer Champion universities, we present:

- The evolution of multiple mathematics pathways in these universities;
- The impetus for moving toward and executing the shift to multiple pathways, including strategies to overcome key challenges; and
- Implementation advice for other four-year institutions and their community college transfer partners.

The message for community colleges implementing pathways consistent with the Dana Center Mathematics Pathways principles is clear: Multiple mathematics pathways are an established approach among many Texas four-year universities. Their use of statistics, quantitative reasoning, and STEM-prep pathways anchored in standard learning outcomes for transferable courses are well aligned with DCMP pathways and their content. While more work is necessary to ensure that DCMP pathways are aligned for seamless transfer with every four-year institution in their region, the experience of these innovative universities are invaluable for institutions that are striving to align two- and four-year math pathways. //

*The term *non-algebraically intensive* intentionally suggests that statistics and quantitative reasoning pathways are not completely devoid of algebraic content. The necessary mathematics in a statistics or quantitative reasoning course often reviews and deepens students' understanding of basic algebraic reasoning; however, this is not the primary focus of the curriculum.

THE DANA CENTER MATHEMATICS PATHWAYS TRANSFER CHAMPIONS INITIATIVE

The goal of the Dana Center Mathematics Pathways is to increase student success in developmental mathematics, entry-level college mathematics, and completion of a degree, license, or certificate with labor market value. The DCMP's Transfer Champions Initiative supports collaboration between two-year and four-year institutions to align mathematics requirements and pathways. Improving the predictability of transfer pathways and the applicability of mathematics courses to majors helps ensure that mobile students preserve earned credits, do not need to repeat or replace coursework, and can move efficiently toward their completion goals.

MOVING AWAY FROM "COLLEGE ALGEBRA FOR ALL"

EACH DCMP TRANSFER CHAMPION UNIVERSITY implemented its own variant of multiple mathematics pathways, building from its particular history, program offerings, and institutional priorities. Echoing William Cherry's critique at the University of North Texas, these institutions viewed the dominance of college algebra as the first college-level math course, regardless of major, as problematic for both students and faculty.

Several of these universities, including The University of Texas at Austin and The University of Texas at Tyler, removed college algebra from their core curricula, while others sought to encourage more balanced enrollment levels among college algebra and appropriate alternatives. Some universities started their redesign efforts with a strong interest in a statistics pathway; others began with the quantitative reasoning course based on faculty interest or experience, or the needs of partner disciplines.

Making college algebra the default introductory math course was a disservice both to students who needed higher level math in their STEM majors and to students whose programs required statistics or math reasoning skills. According to Deborah Pace, associate dean of the College of Sciences and Mathematics at Stephen F. Austin State University (SFA), faculty recognized that insisting on the same, one-size-fits-all, algebra-based curriculum for all SFA students was not appropriate for everyone. Students who were going into STEM fields needed a deep conceptual understanding of college algebra and its applications; however, the typical college algebra class enrolled many students who did not see themselves in math- or science-intensive careers and were frustrated trying to master a curriculum designed for students headed to STEM majors. According to Pace, "With these mixed audiences in college algebra, we often ended up trying to serve the middle. And when you aim at the middle, you often do not serve either side of the middle very well."

> "If college algebra has become a significant barrier to obtaining a degree and it is not a tool used after graduation, then we have to look at why that barrier is maintained."
>
> — CELIA WILLIAMSON, *UNT*

College algebra was an avoidable roadblock for too many students. Historically, about half of the students who took college algebra failed the course. Virgil Pierce, associate professor of mathematics at The University of Texas–Pan American (UTPA), estimated that at least a third of the students taking college algebra at UTPA do not really need it. Yet, by taking the course with such a high failure rate, many students are putting their progress toward a degree at risk. Pierce felt that "college algebra shouldn't be used as the way to weed out students." Williamson of the University of North Texas agreed: "If college algebra has become a significant barrier to obtaining a degree and it is not a tool used after graduation, then we have to look at why that barrier is maintained."

Mathematics faculty and their students were frequently frustrated by the overemphasis on college algebra. Many faculty members in fact did not like teaching introductory college algebra. Sheldon Davis, chair of the mathematics department at The University of Texas at Tyler, noted that "the students were failing; they were angry; they didn't understand why they had to be there." Math faculty, seeing their students' frustration and high rates of failure, were eager to explore better options. //

TAKING ACTION
TO IMPLEMENT MULTIPLE PATHWAYS

ONCE AN INSTITUTION'S LEADERS and faculty see the need for and potential benefits of moving toward multiple mathematics pathways, the university must then embrace and implement the many complex changes that such a move requires in curriculum, clarification of program requirements, advising, catalog revision, and communication with transfer partners. Ample sources of inertia can prevent an institution from modernizing its mathematics program. Institutions that have been successful typically describe a catalyzing problem that focused coordinated action across math faculty, faculty from partner disciplines, administrators, and advisors.

The pivotal moment for some Transfer Champion universities was reviewing their current curricula and student performance. For example, Stephen F. Austin University reviewed single college-level courses, such as Mathematics and Society (Math 110); the University of North Texas reassessed their core curriculum; Texas Tech University held discussions with faculty about data on DFW rates (non-passing grades) in different courses and how they might be reduced; and The University of Texas at Austin reviewed its entire undergraduate math curriculum.

Historically, few students at The University of Texas at Austin took college algebra: Most began in calculus. A review of the university's three-course calculus sequence revealed gaps in preparation for students in the social sciences and biological sciences, who needed a much deeper understanding of probability and statistics. These conclusions spurred the development of robust statistics courses and, later, a new statistics department to better meet student needs.

At Texas Tech University, located in sparsely populated West Texas, modernizing the mathematics program and making program math requirements

simpler, more coherent, and more transparent became an important part of the university's transfer strategy. The university aggressively courted transfer students from around the state to increase enrollment and raise academic standards. To attract such students to Lubbock, Texas Tech administrators focused on efficient transfer of credits and their application to majors, a competitive edge that students value.

For some of the other Transfer Champions, aspects of the university's operational model played a catalytic role. The University of Houston–Downtown (UHD) was an open admissions institution until fall 2013 and, each year, enrolled a large group of incoming students with significant developmental education needs. Redesigning developmental math to increase student persistence and graduation rates, therefore, was a high priority for UHD. The university reviewed both algebra- and non-algebra-based courses and explored how to better align developmental instruction with the range of first college-level math courses. For The University of Texas Rio Grande Valley (UTRGV), its creation through the consolidation of The University of Texas-Pan American and The University of Texas at Brownsville accelerated its own review and revision of the math program along pathway lines.

Frequently, the spark for moving from concept to reality was the appointment of a new mathematics department chair and the ensuing review of existing mathematics programs, courses, and outcomes. At UT Tyler, however, it was the math faculty, not the department chair, who took the lead. At Texas Tech and Stephen F. Austin, the faculty in the disciplines were the initial driving force for change. Recognizing that math requirements posed a barrier for many of their otherwise successful students, these faculty members asked their respective math departments to help better align math course content with program needs.

Across Texas, two additional factors influenced the discussions and timing of university transitions to multiple pathways. The role of discipline associations was important in supporting the shift to an appropriate math pathway for its future professionals. When the nursing associations recommended that statistics become the preferred math competencies for nursing graduates, nursing programs across the state reassessed their curricula. Debates and resolutions within the Mathematics Association of America and the American Mathematics Association of Two-Year Colleges provided momentum and support for the shift to multiple pathways. The Texas Higher Education Coordinating Board was also influential, particularly in the development of common course learning outcomes for multiple, entry-level math courses and refinement of the common core curriculum. //

> A review ... of the calculus sequence revealed gaps in preparation for students in the social sciences and biological sciences, who needed a much deeper understanding of probability and statistics.

CHALLENGES
IN IMPLEMENTING MULTIPLE PATHWAYS

IT IS NO SMALL FEAT for a higher education institution to create coherent, transparent course sequences and pathways that deliver the math students need in order to succeed in their majors and careers. Faculty can be the most important drivers for these efforts. At the University of North Texas, Celia Williamson saw the importance in addressing questions and concerns of faculty, both in mathematics and the disciplines: What is the math that your students need, particularly if they are not going to major in math? What courses give your students the quantitative skills they need for the careers they are heading toward? What courses do they need as freshmen and sophomores to prepare them for the learning they will be doing in their final two years of college? "If we don't start with that," Williamson explained, "we'll lose those [instructors] whose academic heart is to serve those students with a strong education, and we will be vulnerable to questions of dumbing down the curriculum 'just to get students through,' rather than defining what students really need and how they should get what they need."

> It took time, planning, and perseverance ... to collaborate in ensuring that departmental and university requirements are clear to transfer students as they make their course decisions.

At the same time, creating and offering courses are no guarantee of their uptake by students who would benefit from them. Advisors or students may not always be aware of new math pathways or are not certain which math pathway is most appropriate for a particular program; additionally, students may not have yet selected a program of study. The contemporary math course offered at UT–PA fills only three or four sections a semester, even though math department administrators would like to see enrollment across college algebra, statistics, and contemporary math parallel the distribution of students in STEM fields, social science programs, and liberal and fine arts, respectively. At UHD, a statistical literacy course created as a third option alongside college algebra and quantitative reasoning filled only one section in spring 2015. Bill Waller and Tim Redl of the university's mathematics department readily acknowledged the need for more aggressive marketing, better outreach to advisors, and discussions with discipline faculty, particularly in the social science or liberal arts majors, whose students would benefit from taking the statistical literacy course rather than algebra.

Accurate and consistent advising is especially critical when implementing multiple pathways. When the Transfer Champion institutions began moving away from college-algebra-for-all, student advisors were often the first to resist. For years, they had advised students to take algebra because it was "the safest bet." That is, if students were uncertain about choosing a major or if there was a possibility of changing majors, then they were advised to take college algebra because it was the most widely accepted math course across STEM and non-STEM majors. Many advisors, therefore, were reluctant to help implement multiple pathways initially, as they considered it their responsibility to protect students from the risk of having to take college

algebra later to meet program requirements.

Student mobility and transfer compound the advising challenges concerning which mathematics courses students should take in order to progress toward a major and degree. Many universities and community colleges have moved to multiple math pathways, while others have not. Even among those institutions that have robust statistics and quantitative reasoning pathways, math course requirements can differ for the same major across institutions. Variation in requirements creates significant burdens for advisors and students, who must stay abreast of this information—often across many possible transfer institutions that community college students are considering.

It takes significant time and effort to plan and implement multiple mathematics pathways. Transfer Champion university leaders noted that there were no easy ways to reach faculty in the disciplines or to communicate efficiently with advisors. It took time, planning, and perseverance to gather the right faculty members, staff, and administrators to discuss and make decisions on changes to program requirements, course content, and advising messages. Similarly, sufficient time and planning were needed for four-year universities and their community college partners to collaborate in ensuring that departmental and university requirements are clear to transfer students as they make their course decisions.

In recent years, each of the Transfer Champion universities in Texas overcame these challenges by pursuing strategies that engaged, informed, and motivated important constituencies—faculty, advisors, and of course students. Their remarkable efforts resulted in new math pathways that are well designed and earn the support of key mathematics and discipline leaders. Their goal was that, once implemented, these pathways will meet the students' needs and become well-established, popular options. //

RECOMMENDATIONS
FOR EFFECTIVE MULTIPLE PATHWAYS IMPLEMENTATION

IMPLEMENTING multiple mathematics pathways requires attention to both supply and demand—the supply of robust, high-quality mathematics offerings, and students' demand for those options and alternatives, particularly from students pursuing majors that do not require algebra-based courses. While all seven universities featured in this case study made great strides toward implementing their vision of multiple mathematics pathways, many acknowledged that they still need to improve advising, boost enrollment, and coordinate math pathways with regional partners to enhance the predictability of credit transfer and applicability to improve transfer student success.

The following recommendations, distilled from the experience of these institutions, offer strategies for institutions planning to develop multiple pathways and for those where implementation is underway but not yet scaled.

DEFINE THE PROBLEM
so that the case for collective action is clear.

As in any change process, the critical first step is to look at the data and create a clear problem definition so that the case for curricular reform gathers support and momentum. Faculty and administrators at Transfer Champion universities collected and reviewed student data on math course performance to identify high-leverage opportunities for improvement. Most of these institutions targeted student success in gateway courses and student progress (or lack of it) through course sequences such as the calculus preparatory sequence. Other institutions identified challenges among developmental mathematics or transfer students, and organized data collection and analysis in these domains. Important information can also be gained by asking department heads and program chairs about existing math course offerings and their effectiveness in preparing students in their programs of study.

ENGAGE FACULTY AND ADMINISTRATORS
across math and other departments.

Progress in designing and implementing multiple math pathways requires faculty and administrators to champion the change. Institutions that have successfully implemented multiple math pathways developed an evidence- and data-based narrative explaining why multiple pathways benefit students and the institution. Faculty and administrative leaders described taking their narrative "on the road" and targeting key influencers in the math department, the administration, and the most important disciplines at their institution. Part of the strategy to help build the broad coalition needed to implement math pathways was to secure confidence that the process will be thoughtful and inclusive and will prioritize student success. Ryan Gibbs of Texas Tech articulated the importance of such strategies: "The key is always to get the right faculty in the room."

Suggested action steps include engaging math faculty and department leadership in an assessment of current math course offerings; determining whether to develop new courses; and working with partner disciplines to refine existing courses to meet student needs. Administrators play an essential role in supporting these activities, ensuring that changes are approved and coordinating the work of the math department with myriad partner disciplines.

INVOLVE ADVISORS
so that students get the right messages.

Advisors are best positioned to steer more students to the appropriate math courses for their needs. Virgil Pierce of the University of Texas–Pan American recommended helping advisors convey to students that taking the "right math" can increase their likelihood of completion and also save them time and money if they pass their courses on the first try.

Since discipline faculty and advisors do not interact with students until they have selected a major, it is crucial to work with the advisors who meet with freshmen and to help those students understand the benefits of non-algebra pathways. At The University of Texas at Tyler, an office of academic success was created with the sole purpose of supporting and advising freshmen. The freshman advisors were initially the most skeptical group about the multiple pathways initiative, since they worked with so many undecided students. Targeted outreach to these advisors was a turning point in advancing the multiple pathways strategy at UT Tyler.

ENSURE NEW MATH PATHWAYS ARE TRANSFERABLE
and specify math requirements for each major.

The shift away from college-algebra-for-all represents a significant change for transfer students. Advising and institutional practices have long centered on using college algebra as the default for students who intend to transfer. Regular communication and consistent messaging with transfer partners about the goals and expectations for modern mathematics pathways are needed to modify practices based on long-held traditions. In addition, when university pathways use standard courses from the Academic Course Guide Manual, communication is simplified and student's earned credits are preserved at Texas public institutions of higher education.

Lack of clarity and transparency about changes to math sequences can delay implementation and student take-up. To help allay student, faculty, and advisor concerns and to promote better decisionmaking, universities have generated program maps for the course sequences and requirements of specific majors. Disseminating these maps widely—using web and print outreach—and tailoring them for advisor or student audiences are important. Maps help these two key constituencies to understand the requirements easily and have their questions answered quickly. It is important to provide clear recommendations about which math course is most suitable if programs allow students to take one of a few different courses to meet a math requirement. Universities suggested several strategies that can be used to reinforce student placement into the most suitable course. For example, some Transfer Champion universities list the recommended course first in the course catalog and on the web (not by lowest course number, as is often the default). They eliminate courses that are not recommended or list other acceptable options after the recommended course.

Data on implementation trends by major can play a vital role in helping institutions assess successes and address any remaining challenges. For example, institutions may try to determine if students in targeted majors are enrolling in the appropriate math pathway. Analyzing student data for particular courses and majors also provides feedback on whether predicted benefits to students in specific majors are accruing, informing any needed modifications or improvements.

SITUATE MATH PATHWAYS IN A BROADER REDESIGN
of credential programs.

The goal of implementing multiple mathematics pathways is to help students enroll in and learn the math needed for program and career success. Of course, many community college and four-year students do not always start school with a chosen major or clear career goal. The longer they take to decide, the more difficult it is to make good decisions and achieve their goals efficiently. Ultimately, multiple math pathways should be seen as one element of a broad strategy to support and accelerate students' decisionmaking about their programs, courses, and careers through more transparent pathways, program maps, and advising. Multiple math pathways are consistent with the Community College Research Center's recommendation that a "guided pathways" model replace the "cafeteria style, self-service" approach to higher education.[12] To maximize success, the introduction of multiple math pathways needs to be aligned with the redesign of developmental education, program and major selection, acceleration to completion, and alignment across different segments of education (K–12, community college, and four-year). It will have the most lasting impact as one important piece of a student-focused approach to better decisionmaking, resulting in less drift, more focus, and better student outcomes.

COMMUNICATE REGULARLY WITH TRANSFER PARTNERS
so they understand program requirements and know their university colleagues.

The applicability of math courses to majors is a difficult issue for universities because it demands a high degree of coordination within and across institutions. Clarifying specific math requirements of each major, particularly those that are likely to attract large numbers of transfer students, is critical to ensuring that new math options gain traction and enrollments. Better communication with community college faculty can clarify expectations and the nature of the alignment with four-year courses. At Texas Tech University, for example, meetings with transfer partners typically include comparisons of textbooks and syllabi. Communicating with community college advisors about new options and requirements is also essential. Both community college advisors and students need to feel comfortable answering not just the question "Will this math course transfer?" but also "Will it be accepted in my major?"

Engaging with transfer partners around these key questions creates the opportunity for regional alignment of mathematics pathways and requirements across the region's two- and four-year institutions. This alignment can be negotiated between pairs of institutions. For example, at The University of Texas at Austin, math faculty conduct workshops for their peers at Austin Community College, a process that promotes cross-institutional relationships and trust. Alternatively, a more comprehensive approach is possible through a regional convening of math faculty and instructional leaders from different institutions. The Dana Center organized a regional meeting of four-year universities and their two-year transfer partners in Kilgore, Texas, for East Texas schools. Several other meetings are planned for other regions in Texas during the 2015–16 academic year. Regional convenings can spark the development of specific, regional program-to-program maps and regional Memorandum of Understanding or articulation agreements so that faculty, advisors, and students enrolling in any of the region's public institutions clearly understand the expectations and requirements of other schools in the region. Keeping student needs at the fore and focusing on helping them make wise decisions about courses, programs of study, and transfer options will foster a shared sense of responsibility for mobile students.

COMPARE SCHOOL REQUIREMENTS AND POLICIES
with those of other institutions in the state.

The work of four-year universities and community colleges in Texas to develop multiple mathematics pathways yields an increasingly easy path for others to follow. Representatives of Transfer Champion universities frequently emphasized the importance of knowing and understanding what their peer institutions are doing. Deborah Pace of Stephen F. Austin University explained, "Most regional universities want to know what the others are doing: what they are dealing with and why; what they are doing that is having success; and how they are doing it efficiently." Cross-institutional sharing of practices and policies enables universities to gain credibility and build political support at their own institutions. Such communication also helps universities identify opportunities for aligning with precedents set in other institutions regarding math requirements for particular majors or for approaches to transfer issues. An institution can compare its progress with that of peer institutions to help accelerate consensus, plans, and implementation and to help secure support from state actors.

The Dana Center, the Texas Association of Community Colleges, and the Texas Higher Education Coordinating Board (THECB) can provide useful resources to colleges and universities that are planning multiple mathematics pathways. The Dana Center Mathematics Pathways *Implementation Guide* provides detailed action steps related to math pathways implementation (this resource is not limited to implementation using the DCMP curricular resources). The Dana Center's *Mathematics Pathway Transfer Inventory* offers a frequently updated comprehensive list of math requirements for all majors at public universities. The Dana Center and THECB follow and publicize trends in core curriculum requirements across the state's colleges and universities. //

FINAL THOUGHTS

THIS CASE STUDY HIGHLIGHTS the promising activities of seven leading universities in Texas that developed multiple math pathways. Consistent with national and state trends in undergraduate mathematics offerings, the Transfer Champion universities agreed that college algebra should no longer be considered the default mathematics for students. Pathways through statistics and quantitative reasoning were developed, approved, and integrated into program requirements and advising protocols, with the invaluable support of math and partner discipline faculty, administrators, and advisors.

This study offers insights about the structure of multiple pathways and the process by which pathways were implemented at these Texas universities. Each identified a catalyzing problem of student success relevant to their institutional context, and each created a data-informed narrative to justify and guide the institutional reform effort. Leaders emerged from the mathematics or partner disciplines or administration to make the case and support the multiple math pathways vision for improving student outcomes. In each university, innovators encountered some resistance but found different ways to address issues. The Transfer Champion universities identified strategies to overcome inertia and preference for the status quo; build and institutionalize pathways through broad stakeholder engagement, training, and professional learning opportunities; secure course and program requirement approvals; and implement targeted outreach to transfer partner institutions.

Although each university's story is unique, there is broad agreement among the featured universities about undergraduate mathematics course offerings that are aligned to students' programs of study. Pathways through statistics, quantitative reasoning, and calculus preparation sequence have become normative offerings that serve large numbers of students and majors. The pathways described here are also consistent with the efforts of the Dana Center Mathematics Pathways, providing a strong signal about common expectations in undergraduate mathematics courses.

Although each university's story is unique, there is broad agreement among the featured universities about undergraduate mathematics course offerings that are aligned to students' programs of study.

Cross-institutional alignment and predictability are especially beneficial for transfer students, who expend valuable time and resources retaking or replacing coursework that does not transfer or does not align with their intended degree program. While many institutions have already adopted a math pathways approach, others maintain a more traditional approach.

It is our hope that the experiences and recommendations of the Transfer Champion universities will help mobilize and inform similar change processes at those colleges and universities that may be future adopters, so that all Texas students can benefit from a more coherent and aligned system of undergraduate mathematics pathways. //

ENDNOTES

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The Dana Center develops and scales math and science 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.

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