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A Top-Down/Bottom-Up Approach to Statewide Change

Mathematics Pathways to Completion

Susan Bickerstaff | Adnan Moussa

CCRC COMMUNITY COLLEGE RESEARCH CENTER
TEACHERS COLLEGE, COLUMBIA UNIVERSITY

CCRC COMMUNITY COLLEGE RESEARCH CENTER

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The Community College Research Center (CCRC), Teachers College, Columbia University, has been a leader in the field of community college research and reform for over 20 years. Our work provides a foundation for innovations in policy and practice that help give every community college student the best chance of success.

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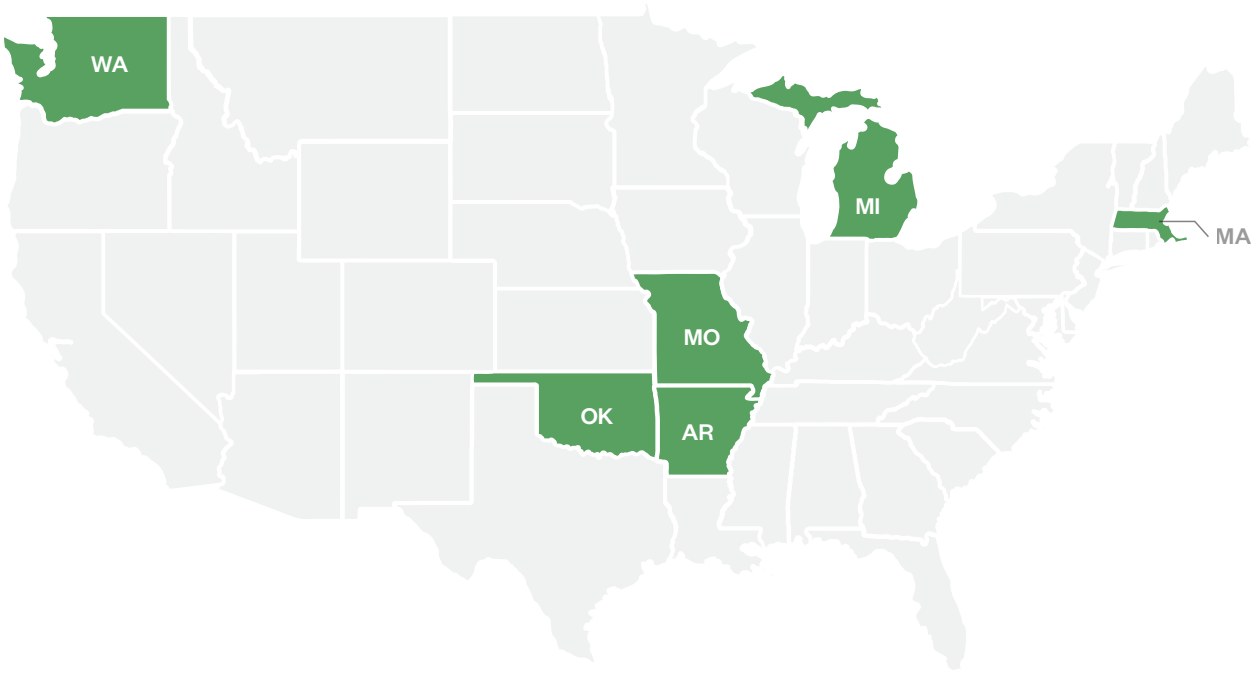
States Participating in the Mathematics Pathways to Completion Project



Inside This Report

This study examines the efforts of higher education systems in six states to implement large-scale changes to improve student outcomes in mathematics in community colleges and four-year colleges and universities as part of the Mathematics Pathways to Completion (MPC) project. Led by the Charles A. Dana Center at The University of Texas at Austin, the three-year project was launched in 2015 to help Arkansas, Massachusetts, Michigan, Missouri, Oklahoma, and Washington adopt the Dana Center Mathematics Pathways model, largely by facilitating cross-sector and cross-institutional collaboration. The goal was for these states to implement mathematics pathways as a "normative, sustained, and institutionalized practice" for all students in all public postsecondary institutions (Ortiz & Cook, 2019, p. 73). In many postsecondary contexts, college algebra has traditionally been the default entry-level transferable mathematics requirement. By contrast, in a mathematics pathways approach, students' introductory college-level mathematics course is aligned with the quantitative skill needs of their program of study. Common mathematics pathways courses include precalculus, statistics, and quantitative reasoning. Students who need additional academic support to succeed in these courses participate in courses or services that are aligned with their mathematics pathway.

This final report of the MPC project describes how the Dana Center's project design supported participating states in navigating challenges related to implementing mathematics pathways statewide and offers examples of how states made progress toward their goals. In this report, we describe the Dana Center's theory of scale, which combines "top-down" policy changes that enable reform implementation with "bottom-up" flexibility that allows individual institutions to adapt and develop approaches to fit their context (Cullinane, Fraga Leahy, Getz, Landel, & Treisman, 2014). Drawing on institutional surveys, self-assessments by state leaders, stakeholder interviews, and project documents, this report explores two overarching questions:

1. How did states engage diverse stakeholders across higher education sectors using a top-down/bottom-up approach to implementing mathematics pathways at scale statewide?
2. What challenges did states encounter in implementing mathematics pathways statewide, and what successes resulted from their work?

The report's findings are organized across three phases of state-level work.

Phase 1: Building Urgency and Motivation for Change

To build urgency and motivation for change, the Dana Center guided each of the six states to form a faculty-led task force representing all public sectors of higher education. A primary goal of these task forces was to come to a consensus on and publish a set of recommendations related to mathematics pathways implementation in their respective states. Unlike top-down reforms that are devised primarily by policymakers or legislators, the recommendations developed by the task forces

were sensitive to institutional conditions and responsive to real challenges faced by instructors and students in the classroom. Task force recommendations focused on improving the transferability and applicability of existing mathematics courses to programs of study within and across institutions, reconsidering developmental and college-level prerequisite courses, and providing stakeholder education and professional development.

Phase 2: Setting the Conditions for Statewide Scaling

Once they published these recommendations, task forces were responsible for setting detailed goals for the full-scale implementation of mathematics pathways statewide, including the number of pathways and their structure, the alignment of pathways with programs of study, the placement of students into each pathway, and the evaluation of student success. Like other parts of the MPC project, the plan for scaling mathematics pathways statewide was left up to each state to determine based on its specific context. In conjunction with developing this plan for scaling, states used a working group structure to come to a consensus on student learning outcomes for mathematics pathways courses. Having common outcomes statewide aided states in enhancing the courses' transferability and program applicability.

Phase 3: Building Capacity to Implement Mathematics Pathways at Institutions

In the final phase of the MPC project, task forces secured commitments and institutional action plans from colleges and universities planning to begin implementing mathematics pathways in accordance with the parameters developed by each state's task force. At the project's conclusion, 88 institutions, representing 62% of public institutions in five states, had committed to implementing mathematics pathways for the 2018–19 academic year. States customized their approach to securing institutional commitments based in part on their degree of statewide centralization. To support institutional implementation, state task forces and the Dana Center provided an array of resources and supports to institutions on topics including curriculum development, advisor outreach and training, corequisite remediation, and faculty professional development.

The ultimate results of these efforts are unknown; by design, institutions were beginning their mathematics pathways implementation at the project's conclusion. Nevertheless, the MPC project provides an example of how higher education systems can work across governance structures and higher education sectors to take on large-scale reform.

Introduction

The imperative to scale new, evidence-based policies and practices intended to improve student outcomes is acutely felt by states that have adopted college completion goals and accountability measures, such as outcomes-based funding. But as past studies have documented, scaling reforms to instruction, advising, program structure, and other areas in higher education is challenging (e.g., Kezar, 2018; Quint et al., 2011). Within institutions, reforms are often initiated at a small scale and without broad-based input and support, hampering efforts to expand them. Within systems and states, reformers can likewise struggle to build a consensus around problems and solutions, devise strong resources for institutional implementation, and gain institutional commitment to reform.

This study examines the efforts of six state higher education systems to implement large-scale changes to improve student outcomes and close opportunity gaps in mathematics in community colleges and four-year colleges and universities as part of the Mathematics Pathways to Completion (MPC) project. Led by the Charles A. Dana Center at The University of Texas at Austin, the project was launched in 2015 to facilitate cross-sector and cross-institutional collaboration in adopting the Dana Center Mathematics Pathways (DCMP) model for undergraduate mathematics. Each of the participating states—Arkansas, Massachusetts, Michigan, Missouri, Oklahoma, and Washington—had the goal of implementing the DCMP model statewide. The MPC project was informed by the Dana Center's theory of scale and intended to help states and institutions make mathematics pathways a "normative, sustained, and institutionalized practice" for all students at all public postsecondary institutions (Ortiz & Cook, 2019, p. 73).

The DCMP model is one type of mathematics pathways reform designed to align students' entry-level mathematics courses with their academic and career goals and allow earlier access to college-level mathematics courses.[1] In many postsecondary contexts, college algebra has traditionally been the default entry-level transferable mathematics requirement. Postsecondary students have typically been placed into college-level mathematics based on assessments of their algebraic skills, and students deemed underprepared for college-level coursework have been required to complete lengthy algebra-based developmental mathematics sequences. These course sequences have been major stumbling blocks for student success, particularly for students from traditionally marginalized groups (Burdman, 2018). In addition, reformers have increasingly argued that college algebra does not confer the numeracy and reasoning skills that students need to succeed in college and beyond (American Mathematical Association of Two-Year Colleges, 2014; National Council of Teachers of Mathematics, 2018). By contrast, in a mathematics pathways approach, students' introductory college-level mathematics courses are aligned with the quantitative skill needs of their program of study. (Common mathematics pathways courses include college algebra,[2] statistics, and

In a mathematics pathways approach, students' introductory college-level mathematics courses are aligned with the quantitative skill needs of their program of study.

quantitative reasoning.) These changes are also generally accompanied by changes to developmental mathematics, with students who need additional academic support participating in courses or services that are aligned to their mathematics pathway.

The challenges associated with implementing and scaling mathematics pathways are multifaceted and involve policies, practices, and perceptions within mathematics classrooms, mathematics departments, institutions, and higher education systems. For example, if too few mathematics faculty are prepared to teach non-algebraic mathematics courses, it will hamper a department's ability to offer enough sections of courses such as quantitative reasoning or introduction to statistics. If departments do not currently offer such courses, faculty must invest significant time in determining learning outcomes and designing curricula. At the institutional level, if program requirements are not adjusted so that these courses count toward a student's major, college algebra will remain the default mathematics course for students. At a system level, students who intend to transfer will not be inclined to enroll in mathematics courses that will not apply to degrees across institutions, and advisors are unlikely to advise students to take mathematics courses that they do not believe are transferable and applicable to students' majors.

This final report of the MPC project describes how the Dana Center's project design supported participating states in navigating these challenges and examines how states made progress toward implementing mathematics pathways at full scale. Drawing on institutional surveys, self-assessments by project leaders, stakeholder interviews, and project documents (described in detail in the appendix), this report explores two overarching questions:

1. How did states engage diverse stakeholders across higher education sectors using a top-down/bottom-up approach to implement mathematics pathways at scale statewide?
2. What challenges did states encounter in implementing mathematics pathways statewide, and what successes resulted from their work?

This examination of how states engaged in implementing and scaling mathematics pathways statewide can inform the efforts of other states working to implement coordinated efforts to improve mathematics outcomes for students in higher education.

The Mathematics Pathways to Completion Project

The Dana Center's Theory of Change at Scale

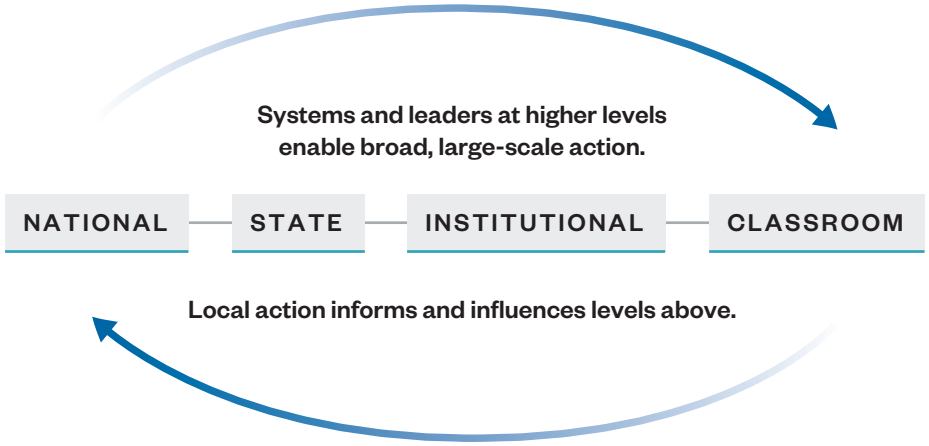
The MPC project was launched at a time when increasing accountability in the broad-access public higher education sector drove state and system policymakers to mandate changes to developmental education. For example, the Texas State Legislature passed a bill in 2017 that requires all public institutions to enroll 75% of their developmental education students in corequisite remediation models by 2020 (Smith, 2017). In 2012, Connecticut legislators required that all public institutions use multiple measures for course placement and offer no more than a single semester of developmental education. Other legislation in Florida, California, and other states has impacted developmental education placement and course delivery methods in higher education (Hu et al., 2014; Rodriguez, Cuellar Mejia, & Johnson, 2018).

State legislation can lead to expeditious and widespread reform implementation resulting in increases in student success (e.g., Park et al., 2016). Legislation can quickly transform "scattered progress" into large-scale coordinated change (Mullin, 2018). At the same time, top-down mandates are often designed by policymakers who may not be knowledgeable about the nuances of institutional implementation (e.g., Park, Tandberg, Hu, & Hankerson, 2016; Turk, Nellum, & Soares, 2015). Therefore, they may leave many open questions about best practices for implementation. When top-down reforms concern course structure, content, and delivery, which are carried out in day-to-day interactions between faculty and students, they may lead to disaffection among faculty and others charged with on-campus implementation. Despite the challenges of a top-down approach, absent policy change through legislation or other means, reform adoption is likely to be uneven, and scaling innovation can stall. Local, bottom-up implementation is frequently enabled by top-down support (Honig, 2004). The Dana Center recognized the power of combining top-down and bottom-up approaches and structured the MPC project accordingly.

The Dana Center developed a theory of scale that is attentive to multiple levels of the higher education ecosystem, including the classroom, the institution, the system, the state, and the national context.

Based on their experiences supporting mathematics pathways implementation across institutions in Texas, the Dana Center developed a theory of scale that is attentive to multiple levels of the higher education ecosystem, including the classroom, the institution, the system, the state, and the national context (as illustrated in Figure 1). This vision combines top-down policy changes that enable reform implementation with bottom-up flexibility that allows individual institutions to adapt and develop approaches to fit their context (Cullinane et al., 2014). This multilevel coordination is intended not only to ensure the reach and breadth of the reform but also to facilitate depth of implementation within local contexts so that students receive the maximum benefit promised by the innovation (Ortiz & Cook, 2019).

Figure 1.
The Dana Center's Model for Change at Scale (Ortiz & Cook, 2019, p. 66)



Note. Figure adapted with permission from the Charles A. Dana Center, The University of Texas at Austin.

Importantly, the Dana Center's vision for reform at scale was designed at the state level. Coordination of mathematics pathways design and implementation across the two- and four-year sectors is critical for the increasingly mobile postsecondary student population. Upwards of three fourths of incoming two-year college students indicate that they intend to transfer and earn a bachelor's degree (Jenkins & Fink, 2015). Students who begin in four-year institutions are also likely to change institutions, with 36% of four-year students transferring within six years. Among all transfer students who begin in public institutions, more than 75% transfer within their state (Shapiro et al., 2018).

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The design of the MPC project reflected a statewide top-down/bottom-up approach, with a task force comprising mathematics faculty and state-level leaders setting state-level goals and developing a plan for implementation. While the Dana Center set a broad goal for mathematics pathways to become normative practice, states were afforded discretion in their approach to meeting that goal (The University of Texas at Austin, Charles A. Dana Center, 2018a). For example, participating states were free to decide which mathematics pathways to offer; the programs with which these pathways would be aligned; their goals and timeline for scaling; the learning objectives, content, and curricula of the courses in each pathway; and the mechanisms for assigning students to developmental education and helping them reach college-level proficiency. In addition, the Dana Center did not require a particular policy approach for ensuring course transferability or incentivizing institutional participation. Instead, the Dana Center advised states on a set of processes for stakeholder engagement and decision-making and provided resources and supports to aid states as they engaged in these processes.

The six states that participated in this project vary in size, history of mathematics reform, and postsecondary governance (as described in Table 1). The goals, timelines, and processes on which the task forces decided for their MPC work also varied. Thus, this project provides a rich context for understanding the range of approaches states might take in enacting statewide reform.

Table 1.
Higher Education Governance Models in Participating States

STATE	PUBLIC TWO-YEAR INSTITUTIONS	PUBLIC FOUR-YEAR INSTITUTIONS	GOVERNANCE MODEL
Arkansas	22	11	Centralized (The Arkansas Department of Higher Education oversees both two- and four-year institutions.)
Massachusetts	15	14	Centralized (The Massachusetts Department of Higher Education oversees both two- and four-year institutions.)
Michigan	28	15	Decentralized (Michigan has no state higher education governing or coordinating body. Institutions are autonomous and governed by elected boards.)
Missouri	14	13	Centralized (The Missouri Department of Higher Education oversees both two- and four-year institutions.)
Oklahoma	16	14	Centralized (The Oklahoma State Regents for Higher Education is the coordinating board for all public higher education institutions.)
Washington	34	6	Decentralized (The State Board for Community and Technical Colleges coordinates and directs two-year colleges. The Council of Presidents is a voluntary association of public four-year institutions.)

Project Details

The three-year MPC project began in 2015 with five participating states: Arkansas, Michigan, Missouri, Oklahoma, and Washington. Massachusetts joined as a sixth partner in 2016. The project was funded by the Bill & Melinda Gates Foundation and Ascendium Education Group. States were invited to apply to participate in the project and asked to demonstrate their capacity and commitment to implementing the DCMP model at scale. The model consists of four principles, which throughout the MPC project guided planning and implementation activities at the state, system, and institutional levels:

1. All students, regardless of college readiness, enter directly into mathematics pathways aligned with their program of study.
2. Students complete their first college-level mathematics requirement in their first year of college.
3. Strategies to support students as learners are integrated into courses and are aligned across the institution.
4. Instruction incorporates evidence-based curriculum and pedagogy.

A growing body of evidence suggests that these principles translate into positive student outcomes, particularly for students referred to developmental mathematics. In a random assignment study of the DCMP model at four colleges in Texas,

researchers found that, compared with students in traditional developmental mathematics courses, those enrolled in courses using the DCMP curriculum were more likely to complete their developmental mathematics sequence, take college-level mathematics in their first year, and accumulate mathematics credits at an increased rate (Rutschow, 2018; Rutschow, Diamond, & Serna-Wallender, 2017). Schudde and Keisler (2019) found similar results when looking at the model's implementation across the entire state. These outcomes are similar to those of other mathematics pathways models that align students' mathematics coursework to their program of study and accelerate their progress to college-level coursework (e.g., Hoang, Huang, Sulcer, & Yesilyurt, 2017; Logue, Douglas, & Watanabe-Rose, 2019; Ran & Lin, 2019).

The MPC project was built around three phases of activity, guided by the Dana Center's theory of scale and carried out by the state task forces:

1. building urgency and intrinsic motivation for change by empowering mathematics leaders,
2. enabling scale by creating the policy and practice conditions for statewide implementation, and
3. building faculty and institutional capacity for implementation.

The Dana Center's theory of scale includes a fourth phase—supporting the deep and sustained scale of mathematics pathways to normative practice—which they intended the states to enter after the conclusion of the MPC project. See Figure 2 for a project timeline.

Figure 2.
The Dana Center's MPC Project Timeline

YEAR ONE (2015–16) Phase 1 Build urgency and intrinsic motivation for change	YEAR TWO (2016–17) Phase 2 Enable scale by creating the policy and practice conditions for statewide implementation	YEAR THREE (2017–18) Phase 3 Build faculty and institutional capacity for implementation	PROJECT CULMINATION (FALL 2018) Phase 4 Support deep and sustained scale beyond the MPC project timeline
Activity • State task forces are formed and write recommendations reports **Key event** • Winter 2016: Dana Center holds first project convening	**Activity** • Task forces create a plan for scale and form working groups focused on student learning outcomes, course transferability, and program applicability **Key events** • Fall 2016: Dana Center holds second project convening • Spring 2017: CCRC conducts first-round interviews	**Activity** • Task forces collect institutional commitments and create plans for supporting implementation **Key events** • Summer 2017: CCRC conducts institutional surveys • Spring 2018: CCRC conducts second-round interviews	**Activity** • Institutions begin mathematics pathways implementation **Key event** • Fall 2018: Dana Center holds final project convening

Across all phases, the Dana Center provided states with guidance on key milestones, recommendations on processes, and templates and expectations for key deliverables. States were also provided modest funds to host events (e.g., task force meetings and workshops), offset travel costs associated with project meetings, and/or compensate faculty leaders for their time. Each state was assigned a consultant who served as a liaison between Dana Center staff and task force leaders. Consultants attended state meetings and events, provided feedback on deliverables, and were available to troubleshoot state-specific challenges. In addition, Dana Center staff hosted three convening events, held quarterly calls with state teams, provided workshops on a range of topics for diverse stakeholders in each state, and disseminated Dana Center–published resources to support state efforts.

Implementing Mathematics Pathways Statewide

In the sections that follow, we describe major milestones in each of the three phases of the MPC project. For each phase, we describe how the project enabled a top-down/bottom-up approach to implementation and how stakeholders at various levels of the higher education ecosystem played a role in these activities. (See Figure 1.) Throughout, we provide examples of successful strategies states employed to overcome challenges and move toward the goal of statewide mathematics pathways implementation.

Phase 1: Building Urgency and Motivation for Change

The Dana Center guided each state to form an MPC project task force comprising mathematics faculty representing all public sectors of higher education, including research universities, comprehensive four-year institutions, and two-year colleges.[3] Each state had at least two mathematics faculty as task force co-chairs—one from a two-year college and one from a four-year university—and at least one system-level representative serving as the facilitator. The task force played a leadership role during all phases of the project.

During Phase 1, task force members were particularly engaged in establishing a vision for mathematics pathways implementation in their state. A major goal was to reach a consensus on a set of recommendations for mathematics pathways implementation. These recommendations were vetted by a diverse array of stakeholders from across the state (e.g., institution leaders, mathematics department chairs, student support professionals) and made publicly available in the form of a task force report.[4]

Task force members developed their recommendations over many months, reviewing statewide data on student enrollment and progress in mathematics and building a consensus on the most pressing challenges in developmental and introductory mathematics and strategies to meet those challenges. The Dana Center

provided significant guidance to the task forces to facilitate this process, including guidelines for facilitators, recommended meeting formats, and suggested procedures for developing recommendations. Task forces were encouraged to create a statement of the problem, define the challenges, and generate a list of recommendations from a set of brainstormed solutions to those challenges. A state task force member explained the process:

> *I think the first thing we did was set goals. Then, we broke into groups and identified challenges [for those goals], and then in the next meeting, people took each one of those challenges as a subgroup to look at recommendations for how to implement or how to address that challenge.*

This process was, in some cases, the first opportunity for representatives from two-year and four-year sectors to collaborate on identifying common challenges and solutions to student success in mathematics. The public nature of the recommendations raised the visibility of mathematics pathways as an approach with broad support. Unlike top-down reforms that are devised primarily by policymakers or legislators, these task force recommendations developed largely by faculty were sensitive to institutional conditions and responsive to real challenges faced by instructors and students in the classroom. The reports helped set the direction for each state's work during the rest of the MPC project. Within the task force, the process of creating the recommendations allowed members to agree on a common vision for mathematics pathways in the state. The dissemination of these reports was then intended to enhance faculty, administrator, and advisor knowledge of and commitment to mathematics pathways across the state.

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The content of the reports reveals how the task forces utilized these documents to articulate a vision for mathematics pathways implementation in their state and to describe how that vision addresses challenges related to student success in mathematics.

Aligning Mathematics Pathways With Program and Transfer Requirements

All six task force reports articulated the need for multiple mathematics pathways aligned with the mathematics needs of students in particular programs of study. Four states named specific mathematics pathways in their recommendations, and two used more general language. Most states acknowledged in their reports that individual institutions offer a range of mathematics courses but that enrollment in courses outside of algebra-based pathways tends to be low, at least in part because these courses frequently count only as a general education requirement and do not fulfill the mathematics requirement for programs of study. Several reports also noted the low proportion of students who take college algebra and then go on to take calculus. As one report explains:

> *Most students enroll in College Algebra, a course designed to prepare students for the algebraic modeling and manipulation required in calculus. Of the students enrolled in a college-level math course in*

> *Oklahoma, 62 percent at community colleges and 38 percent at universities enroll in College Algebra. Over half of these students are not in a degree program that requires Calculus. (Oklahoma Math Pathways Task Force, 2017, p. 3)*

Table 2 shows the survey data collected from institutions ($N = 153$) about the typical patterns of course offerings and enrollments.[5] In fall 2017, one year before institutions were to begin implementing mathematics pathways per the MPC project timeline, 90% of institutions offered college algebra, 80% offered statistics, and 82% offered quantitative reasoning. Despite the availability of these courses, for five states in fall 2016, only 9% of the entering cohort enrolled in quantitative reasoning within one year, and only 14% enrolled in statistics. In most contexts, college algebra appeared to be the default course, capturing about 50% of student enrollments. However, according to survey data, only 6% of college algebra enrollees in these five states went on to take calculus within two years.[6]

Table 2.

Mathematics Course Offerings at Institutions in Participating States, Fall 2017

	COLLEGE ALGEBRA	INTRODUCTORY STATISTICS	QUANTITATIVE REASONING
Institutions offering this course[7]	90%	80%	82%
Institutions with college-level prerequisites for this course	29%	53%	9%
Institutions with corequisite options for this course	41%	14%	28%
Institutions where all students, regardless of developmental placement, can complete this course within one year	57%	39%	71%
Student enrollment in this course for five states, fall 2016	50%	14%	9%

Thus, the task forces' recommendations focused not on creating new courses but on improving the transferability and applicability of courses to programs of study within and across institutions. (*Transferability* refers to whether a course will be accepted for credit at a student's receiving institution, and *applicability* refers to whether a course will be accepted as the mathematics requirement in a program of study). Several reports explicitly mention the need for cross-disciplinary collaboration to achieve this goal. For example, Arkansas's report recommended that "academic disciplines identify mathematics competencies needed for specific programs of study and use competencies to recommend a common transferable mathematics course requirement for each program of study" (Arkansas Math Pathways Task Force, n.d., p. 2). Task forces articulated the need to communicate with a variety of departments to understand the mathematics needs of students enrolled in their programs and then identify the most appropriate introductory mathematics course to meet those needs.

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Reconsidering Prerequisite Requirements

All six states issued recommendations to reconsider developmental and/or college-level prerequisite mathematics requirements. Survey data showed how prerequisite requirements at many institutions conflicted with the DCMP goal of enabling students to complete a college-level mathematics course within one year. For example, as shown in Table 2, among the surveyed institutions across all six states, about 53% reported that statistics courses had a college-level prerequisite (typically college algebra). Thus, it is not surprising that only 39% of institutions reported that all students at their institution, regardless of placement, could complete introductory statistics within one year. Comparatively, 57% and 71% of institutions reported that it would be possible for all students to complete college algebra and quantitative reasoning within one year, respectively.

All six states referenced the need to reform prerequisite developmental courses, with three states issuing specific recommendations related to the implementation of corequisite remediation.

All six states referenced the need to reform prerequisite developmental courses, with three states issuing specific recommendations related to the implementation of corequisite remediation and one of those states further recommending that institutions use multiple measures for developmental placement. At the time of the fall 2017 survey, about half of four-year institutions and 38% of two-year colleges across the six states offered college algebra with a corequisite developmental course. The proportions offering corequisite developmental options for quantitative reasoning and introductory statistics were lower, at 28% and 14%, respectively.

Several task force reports also made general recommendations for evaluating the appropriateness of prerequisite requirements. For example, Missouri's report offered this recommendation:

> *Identify prerequisites for alternative college-level mathematics courses that are aligned to targeted programs of study. The learning objectives and outcomes for these prerequisites should match the skills and knowledge needed by a student to be successful in subsequent courses and should have some statewide consistency. (Missouri Mathematics Pathways Task Force, 2015, p. 10)*

Recommendations like these were intended to prompt conversations about whether algebra-based courses are the most appropriate prerequisites for non-STEM college-level mathematics courses.

Providing Stakeholder Education and Professional Development

Oklahoma, Arkansas, and Washington referenced stakeholder education and professional development in their recommendations, including raising awareness among faculty, advisors, and other stakeholders about mathematics pathways. For example, Washington's task force recommended "[providing] students, faculty, and advisors greater clarity and consistency about math pathways" (Washington Math

Pathways to Completion Task Force, 2017, p. 3). The recommendations suggested that the state task force "identify existing math pathways within two- and four-year institutions and present these college-specific pathways in a consistent visual or graphic form, using common language both internally and across institutions for information and advising" (p. 3). This recommendation reflects that Washington, like many states in the project, had a large number of institutions already implementing mathematics pathways at the start of the project, but that additional work with faculty and advisors was needed to ensure students enroll in the pathway aligned with their program and to enhance statewide coordination.

States also included more specific recommendations about ensuring faculty are well prepared to teach non-algebraic mathematics pathways courses and supported to use evidence-based instructional practices. The Oklahoma task force made a recommendation related to student engagement and the use of applications in introductory college-level mathematics courses, and these recommended learning outcomes were referenced in their recommendation on professional development: "Faculty primarily need time and support to learn about new gateway courses, how they support disciplines in meta-majors, increased incorporation of applications, increased student-centered activity, and supporting academic success skills" (Oklahoma Math Pathways Task Force, 2017, p. 6).

Phase 2: Setting the Conditions for Statewide Scaling

Once states published their recommendations, they entered the MPC project's second phase, focused on setting the statewide conditions to enable the implementation of mathematics pathways at full scale. The recommendations states developed during Phase 1 helped them make progress toward implementing mathematics pathways statewide.

During Phase 2, the Dana Center guided state task forces to create a plan for scaling that set parameters for enacting the recommendations in their report. First, task forces envisioned and set goals for the full-scale implementation of mathematics pathways statewide, including the number and structure of pathways, the alignment of pathways to programs of study, the placement of students into each pathway, and measures of student success. Second, task forces set annual performance benchmarks for institutions' first three years of implementation. Third, task forces developed a strategy for supporting institutions during implementation that could go beyond the project's three-year span. Like other parts of the MPC project, the plan for scaling allowed states the flexibility to implement mathematics pathways at full scale according to their specific contexts. As with developing the recommendations in Phase 1, the Dana Center encouraged task forces to take time to deliberate and create their plan collectively, ensuring that perspectives of state policymakers and faculty from two- and four-year institutions were represented.

Like other parts of the MPC project, the plan for scaling allowed states the flexibility to implement mathematics pathways at full scale according to their specific contexts.

In conjunction with developing this plan for scaling, states undertook three additional major tasks in Phase 2 to set the conditions for institutional implementation. The first was to come to a consensus on course learning outcomes. Having common outcomes aided states in their second and third tasks: enhancing the transferability of mathematics pathways courses and enhancing their applicability to programs of study.

Coming to a Consensus on Course Learning Outcomes

To develop common student learning outcomes for key mathematics pathways courses, states' task forces formed small working groups of two- and four-year mathematics faculty from across institutions, with each working group focused on a single course. While institutions in many states were already offering multiple mathematics pathways courses, only one state had common learning outcomes for its mathematics pathways courses before the MPC project began. The adoption of new learning outcomes did, in some cases, result in changes to existing course curricula, but working groups did not prescribe textbooks or other course materials. The Dana Center disseminated a document to the state task forces that guided them through a bottom-up, faculty-led process for developing learning outcomes (Krueger, 2017). This resource laid out suggested roles and responsibilities for working group members and offered guidance for soliciting feedback from key stakeholders and securing final approval. A task force member in one state described how they enacted the working group process to define common learning outcomes:

The Dana Center disseminated a document to the state task forces that guided them through a bottom-up, faculty-led process for developing learning outcomes.

> *We took a really focused look at the actual learning outcomes. And then each subgroup would bring back what they had talked about to the [task force], and then adjustments were made. That would go back to the campuses, and then we'd get feedback from there. Once learning outcomes were created, each college submitted [syllabi] to the [subgroup] to verify that the learning outcomes that were in the syllabus met the requirements of the state-level learning outcomes.*

States prioritized two to four mathematics courses to address during the learning outcomes portion of the project—most commonly statistics, quantitative reasoning, and a course in the algebra–calculus pathway. However, some states developed outcomes for other mathematics pathways courses as well. For example, Washington focused on cementing a mathematics pathway for elementary education majors. Many institutions in the state offered a two- or three-course mathematics sequence for elementary education majors, and there was interest in enhancing coordination across institutions around this pathway. Oklahoma specified and developed learning outcomes for what they called a "modeling pathway" for students going into business, agriculture, and some social and natural sciences. The introductory college-level course in this pathway would focus on the application of linear, exponential, logarithmic, and other functions.

The Dana Center provided working groups with a list of resources to consult for ideas on outcomes for specific courses (https://dcmathpathways.org/take-action/classroom-level/classroom-level-planning-implementing). Stakeholders reported that they consulted existing learning outcomes for courses in their state; recommendations from professional associations; textbooks; and resources housed on the DCMP website focused on learning outcomes for statistics, quantitative reasoning, and the pathway to calculus. In addition, Dana Center staff offered on-demand, full-day workshops on learning outcomes in two pathways. A calculus pathway workshop was offered in four states. A statistics workshop was attended by teams from five states.

Participants reported that the work of coming to a consensus on learning outcomes and supporting their implementation was often slow and labor-intensive (Bickerstaff, Chavarín, & Raufman, 2018). However, three states successfully developed learning outcomes for all of their mathematics pathways courses during this project.[8] Michigan's three working groups (preparation for calculus, introductory statistics, and quantitative reasoning) published a white paper in 2018 that lists learning outcomes for these three courses and recommendations related to course sequences (Michigan Center for Student Success, 2018). The Arkansas task force used the working group structure to tackle challenges related to prerequisites that were identified in many task force recommendations reports. An Arkansas faculty working group added quantitative literacy as a prerequisite option for a 2000-level statistics course in the statewide course transfer inventory. Previously, that course was available only to students who completed college algebra.

The Dana Center administered a state readiness assessment to project leaders in each state at three points during the project. (See the appendix for a more detailed discussion of this assessment.) Task force leaders were asked to respond to the following statement using a 4-point scale: "Learning outcomes are established for multiple gateway math courses to ensure transferability statewide." All six states indicated growth on this metric across three assessments between January 2016 and October 2017, with two states selecting the highest rating, "well-developed," on the final assessment. (See the appendix for scores.) The process of bringing together faculty from two- and four-year institutions to discuss student learning outcomes surfaced important issues, including discrepancies across sectors and institutions on the goals of gateway mathematics courses. While not every state was able to resolve all of these differences during the project period, cross-sector faculty engagement through the task forces and working groups provided an infrastructure and set of relationships that states may be able to deploy in the future to enhance coordination on course descriptions, outcomes, and even curriculum.

Bringing together faculty from two- and four-year institutions to discuss student learning outcomes surfaced important issues, including discrepancies across sectors and institutions on the goals of gateway mathematics courses.

Enhancing the Transferability of Mathematics Courses

Participating states' efforts to improve the transferability of non-algebraic courses were critical to implementing mathematics pathways at scale. When students, advisors, and other stakeholders are not confident that a particular course is transferable, as is the case for many non-algebraic courses, institutions struggle to increase enrollment in that course.

The Dana Center recommended that each state form a transferability and applicability working group comprising five to seven state- and institution-level administrators representing both the two- and four-year sectors. Working groups were charged with examining statewide student transcript data for transfer patterns and conducting a scan of existing transfer policies in order to recommend enhancements to the transferability and program applicability of mathematics pathways courses. Five states followed this model and received significant support from Dana Center staff in analyzing their data and facilitating conversations about transfer challenges and strategies for mitigating those challenges. One state had an existing transfer infrastructure and elected not to form a separate working group for this project.

The working groups deepened their understanding of the nuances of transfer in their state through the in-depth exploration of data and state and local policies related to transfer. As one stakeholder explained, there is a tendency to reach for relatively simple solutions to the transfer challenge:

> *[They may think], "We updated our transfer portal," or "We passed a policy that guarantees transfer from a two- to a four-year. We solved the issue. We have a policy, so we're done," instead of actually looking at, well, how is it being implemented?*

However, working groups' efforts to enhance course transferability were typically not sufficient in themselves to result in policy changes, at least in part because most working group members did not have decision-making authority for transfer issues in their state. As a result, by the final year of the MPC project, the Dana Center had refined its working group approach to more intentionally engage state policy leaders and to be more responsive to individual state contexts, particularly the degree of governance centralization and existing efforts related to transfer challenges. For example, some systems have transfer or articulation officers, while others have committees or initiatives that oversee course transferability. In some states, the Dana Center extended the working group efforts into a regional approach in which a small team of stakeholders from all colleges in a given region convened to learn about mathematics pathways courses, assess the current challenges with course transfer, and recommend solutions to be implemented in their region. The MPC project showed that faculty working groups can successfully use a bottom-up approach to establish statewide learning outcomes but that resolving transfer issues may require a more customized strategy, contextualized by state and/or negotiated through a more top-down approach.

By the final year of the MPC project, the Dana Center had refined its working group approach to more intentionally engage state policy leaders.

In one example of a state policy–enabled approach to facilitating course transfer, the state legislature in Missouri passed a bill in 2016 to create a general education framework called CORE 42, to be adopted in all public two- and four-year institutions in the state, which also resulted in common course numbering across institutions. The efforts of the task force to create student learning outcomes resulted in four mathematics courses' inclusion in CORE 42: statistical reasoning, mathematical reasoning and modeling, precalculus algebra, and precalculus. Notably, the course description for precalculus algebra signals that it should not be the default course: "Pre-calculus algebra is intended to prepare students for fields of study that would require a high level of algebraic reasoning or calculus" (Missouri Department of Higher Education and Workforce Development, 2018). While Missouri used legislative action to catalyze this change, other states were able to enhance courses' transferability using other policy mechanisms. (See The University of Texas at Austin, Charles A. Dana Center, 2018c, and Schanker & Kazis, 2019, for other examples.)

Enhancing the Program Applicability of Mathematics Courses

In addition to efforts like Missouri's CORE 42 that address course transferability, some states focused attention on the program applicability of mathematics pathways courses. The Arkansas task force began this work by surveying department chairs about the mathematics competencies students need to succeed in their programs of study (Korth, Yu, Watson, Strecker, & Martin, 2018). The results of the survey informed the development of a list of popular non-STEM programs for which quantitative literacy would be a more appropriate requirement than college algebra (Arkansas Department of Higher Education, 2018). During the MPC project, the Arkansas task force began convening disciplinary leaders in these programs to discuss these recommendations and saw some program requirements moving away from college algebra in favor of quantitative literacy. The state conducted a follow-up survey in fall 2019 to quantify how many institutions and programs changed their program requirements in accordance with these recommendations.

Similarly, Oklahoma hosted a series of convenings of department chairs to discuss mathematics needs in their disciplines. These meetings were organized by what the state called "degree clusters," or collections of related programs or majors. A task force member described the goal of these meetings:

> *The goal would be to decide on one common math pathway [for all programs in the degree cluster]. But I think if we can get to two acceptable pathways, that would be a win. I mean, one of the main things that we're looking for is for students who don't need college algebra to not be required to take college algebra. The math group here in Oklahoma has redesigned college algebra to be exclusively geared toward people who need engineering calculus, so the vast majority of students don't need calculus. So, if a political science [program] has college algebra as a requirement right now, our goal is for the department chairs to choose one of the other math options that, hopefully, also will be a common option for sociology and criminal justice, and other similar disciplines that students tend to transfer in between.*

Overall, states made more progress on course transferability than they did on program applicability. As shown in the appendix, on their final self-assessment, five of the six states rated themselves as "well-developed" in response to the statement, "Multiple gateway math courses are included in the general education/core curriculum." However, for the item stating, "A statewide framework for aligning math pathways with broader program areas (meta-majors) is developed and understood by stakeholders," most states rated themselves as "emerging." Two states showed growth on this item across the three self-assessments.

Overall, states made more progress on course transferability than they did on program applicability.

These self-assessments do not reflect efforts in several states that were launching or ongoing during the 2018–19 academic year. However, they are indicative of the complexity of addressing program applicability, as faculty from multiple disciplines and across multiple institutions and sectors must come to a consensus about the mathematics competencies needed for their programs. Despite these challenges, task forces in several states made significant progress in statewide course–program alignment for some disciplines during the project period.

Phase 3: Building Capacity to Implement Mathematics Pathways at Institutions

The goal of Phase 3 was to support institutions statewide in preparing to implement mathematics pathways. Each task force was asked to secure commitments and institutional action plans in fall 2017 from colleges and universities planning to begin implementing mathematics pathways in fall 2018 in accordance with the four DCMP principles. Four states secured these commitments in writing from implementing institutions.[9] These commitments and associated action plans provided assurance that institutions would offer mathematics pathways courses and gave the state task forces critical information to aid in them in designing supports for colleges as they began implementation.

Many institutions were implementing mathematics pathways or associated reforms to developmental mathematics in some form before fall 2018, and the project's design allowed this work to largely continue, with some adjustments to align with MPC project goals. For example, there were institutions in Washington and Michigan that were part of the Carnegie Math Pathways project. As of fall 2017, 71% of institutions in the MPC project states reported that even the lowest placed incoming student could complete quantitative reasoning within one year, and 39% reported all students could complete statistics within one year, which suggests many institutions had the course structures in place for mathematics pathways implementation. (See Table 2.) Because the MPC project was designed around a set of principles rather than curricula, institutions that had previously reformed developmental mathematics could retain elements of their preexisting approach to mathematics pathways. However, even with the freedom allowed under the framework of the MPC project, these institutions were still asked to align course content with new statewide learning outcomes, coordinate cross-disciplinary conversations to ensure mathematics pathways courses were applicable to relevant programs of study, and

scale up the offerings of these courses to ensure all students in applicable programs could take them.

In another example of how the MPC project allowed states to customize their approach, the Dana Center recommended that states take either a tiered or an all-in approach in planning for institutional implementation. States that took the tiered approach secured commitments from a cohort of early-implementer institutions, which would begin implementation in fall 2018. The remaining institutions were to be engaged in mathematics pathways preparation work with a plan for implementation in fall 2019 or fall 2020. In states taking an all-in approach, all institutions were to begin implementation in fall 2018. Considerations for taking an all-in or tiered approach included the degree of state governance centralization (i.e., whether there is a higher education agency that can incentivize or mandate early participation) as well as the degree of institutional readiness across institutions. Of the five states that reached Phase 3 by the end of the project, the three with centralized higher education governance took an all-in approach and secured commitments from all or almost all public two- and four-year institutions in the state. The two decentralized states took a tiered approach, engaging a set of two- and four-year early implementers in fall 2018. (See, e.g., Schanker & Kazis, 2019, for a description of Michigan's approach.)

The Dana Center recommended that states take either a tiered or an all-in approach in planning for institutional implementation.

Supporting Institutional Implementation

To support institutions in preparing for implementation, the Dana Center offered a workshop on designing math pathways in all six states. Each task force encouraged all public institutions in the state to send a cross-functional team of mathematics faculty and administrators. A major goal of the workshop was to prepare and support institutional teams to complete implementation action plans, using a set of Dana Center–created resources designed to guide teams to make decisions about semester-by-semester milestones, deliverables, data collection activities, and communication activities. The Dana Center's implementation guide (https://dcmathpathways.org/implementation-guide) outlines 10 essential actions, such as "establish a leadership team" and "design courses," and steps to achieve these actions. A representative from the Dana Center described what they encouraged institutions to consider when creating action plans:

> *[Let's] say by fall 2018, I want 60% of my sections to be quantitative reasoning. So, they had to back-map each semester and think about what has to happen so I can create a plan of what has to happen to make that vision happen. When does that go to curriculum committee? When does that go to catalog? . . . This is who I need to communicate to. And how am I going to communicate with them? Am I getting the right input and providing the right information?*

To ensure that students could complete college-level mathematics within one year, many institutions also undertook redesigns of their developmental course offerings. As discussed above, all state task forces recommended reforms to developmental

mathematics sequences, and three specifically recommended corequisite remediation. To support such reforms, the Dana Center offered corequisite design workshops in five states. Four of the six states were also participants in Complete College America, an organization that advocates and provides supports for the implementation of corequisite remediation, in addition to other student success strategies.

Interviews with institutional stakeholders revealed the variety of tasks involved in planning to implement mathematics pathways, including curriculum planning and textbook selection, course scheduling management, advisor training and outreach, faculty professional development, assessment and placement reform, and coordination with faculty in non-mathematics disciplines. One stakeholder described the breadth of these activities and the challenges associated with scaling up non-algebraic course offerings:

> *One thing coming up is course scheduling. So, not knowing how many courses [sections] to build has been a cause for concern. And we're anticipating that more students will, now that they're ensured transferability, choose to take the modeling course or the statistics course. That, of course, will depend on the kind of advising they get, the kind of knowledge they get, if they're self-enrolling versus if they're talking to somebody. . . . I think another issue is, if, say, statistics does have a lot of enrollment, do we have enough faculty who feel comfortable in their statistics training to teach those courses? Without the professional development, I'd say, right now, I don't think we do.*

As noted by this stakeholder, the challenges of scaling up non-algebraic mathematics course offerings are linked to challenges of faculty availability and expertise.

Providing Stakeholder Education and Professional Development

Three states recommended stakeholder education for both faculty and advisors in their task force reports. Advisor education and outreach was a major goal of this work because advisor knowledge of mathematics pathways courses was seen as instrumental to scaling. To support this work, the Dana Center offered advising workshops in all six states, which helped faculty and advising staff collaborate to develop a plan for ensuring students receive accurate and clear information about the best mathematics pathway for them, given their academic goals. Washington's task force had set a goal of supporting institutions to ensure that advisors, students, and other stakeholders had clear information about mathematics pathways. To this end, the task force supported institutions to create one-page graphical representations of the mathematics pathways courses they offered and the programs associated with them to help students and advisors understand their options.

Because mathematics pathways can reshape learning outcomes and curricula and thus can have a profound impact on the in-class teaching and learning environment, some states worked to provide faculty professional development to help prepare them to teach mathematics pathways courses. For example, Arkansas's task force made professional development related to teaching quantitative literacy a priority,

and members of the task force organized opportunities for faculty to share expertise within and across institutions focused on instructional practices in those courses. In another example, Oklahoma extended their MPC work through a grant from the National Science Foundation, which the state was awarded in fall 2018 to foster student-centered instruction across all levels of undergraduate mathematics at its 27 public institutions. Called the Mathematical Inquiry Project, this initiative is intended to enhance the effectiveness of hundreds of mathematics faculty and improve the learning of thousands of entry-level postsecondary mathematics students across the state. Oklahoma has planned for this work to occur in three phases. The first will involve understanding and prioritizing the concepts and skills for college algebra/precalculus, quantitative reasoning, modeling, calculus I, and academic success skills. Then, collaborative research and development teams will develop instructional modules for these concepts and skills. Lastly, these teams will lead regional workshops to help faculty learn how to use the modules in their courses and provide ongoing peer mentoring during the modules' implementation.[10]

On their self-assessments, two states reported growth on the metric related to faculty and professional development: "The state provides opportunities and resources for faculty professional development to implement math pathways." One of these two states indicated on its final assessment that this practice was well developed. In interviews with institutional representatives, faculty development was one of the most commonly cited needs related to mathematics pathways implementation; however, providing high-quality professional development is resource-intensive. Given the ambitious scope of the MPC project, designing and offering professional development focused on teaching was not a major activity in most states during the project period.

Strengthening the Quantitative Literacy Pathway at the University of Arkansas at Pine Bluff

The University of Arkansas at Pine Bluff partnered with Complete College America in 2011 to develop a mathematics course called Enhanced Quantitative Literacy (EQL) as a corequisite for its college-level quantitative literacy/mathematical reasoning course. Non-STEM students with ACT scores below 16 are required to take elementary algebra prior to enrolling in EQL, but for those with ACT scores of 17 or 18, taking EQL allows them to bypass intermediate algebra and enroll directly in a college-level course with extra support. However, the mathematics department struggled for years trying to fill EQL sections, reporting that other departments and advisors did not recognize this corequisite option as an appropriate replacement for college algebra.

Since Arkansas began its MPC work, the University of Arkansas at Pine Bluff has raised recognition of EQL as the best course to fulfill non-STEM students' developmental mathematics requirements, both within the university and at other institutions throughout the state. With the support of the state task force, the mathematics department organized ongoing professional development workshops on new pedagogical strategies for full-time instructors in order to increase faculty buy-in and ensure the sustainability of EQL. The mathematics department also rallied support from the vice chancellor to encourage the use of EQL as the non-STEM mathematics requirement, and, in response, the vice chancellor used MPC tools and resources to set up mandatory workshops for advisors and chairs of other departments to explain the benefits of EQL.

In spring 2018, as a result of efforts by the state task force, the Arkansas Course Transfer Review Committee released a report recommending that 12 disciplinary fields accept quantitative literacy as the general education mathematics requirement (Arkansas Department of Higher Education, 2018). These recommendations were endorsed by the director of the Arkansas Department of Higher Education. Since Arkansas completed its work with the MPC project, EQL and quantitative literacy have become applicable to many programs across the state, especially at Southeast Arkansas College, which is the biggest transfer partner of the University of Arkansas at Pine Bluff. College stakeholders attribute increases in the university's retention rates in part to the proper implementation of EQL.

Conclusion

Efforts toward improving overall student success and closing opportunity gaps in higher education have resulted in many small-scale achievements over the past decade. The barriers to scaling up these promising approaches are significant, particularly for multifaceted reforms like mathematics pathways that impact placement, curriculum, advising, and program requirements, within and across institutions and sectors. To accelerate the pace of change and to improve outcomes for transfer students, reformers are increasingly looking to enact reform at the state level, often through legislation and policy change. However, top-down approaches to change may result in policies that do not align with on-the-ground realities, uneven or inconsistent implementation, and a failure to realize the change hoped for by state-level reformers.

In response to these tensions, the Dana Center developed a theory of scale that hypothesized that to implement mathematics pathways across a state or region, stakeholders at multiple levels of the higher education ecosystem would need to be engaged, including faculty, institution leaders, system representatives, and state policymakers. They articulated a vision of a top-down/bottom-up approach to implementing mathematics pathways at full scale in which system leaders would set the conditions for implementation, while faculty and institution representatives would establish a shared vision for mathematics pathways and make decisions on the specifics of institutional enactment. To support states' work, the Dana Center staff and consultants provided significant guidance on recommended processes to meet the project benchmarks, along with resources, including statewide workshops, on pathways design and institutional implementation.

At the conclusion of the MPC project, 88 institutions, representing 62% of public institutions in five states, had committed to beginning implementation in the 2018–19 academic year.

This report describes how six states engaged in this top-down/bottom-up process over a three-year project and provides examples of their approaches and achievements. At the conclusion of the MPC project, 88 institutions, representing 62% of public institutions in five states,[11] had committed to beginning implementation in the 2018–19 academic year. Each state task force, composed of state leaders and mathematics faculty, wrote, vetted, and published a set of recommendations that provided a vision for statewide mathematics pathways implementation; developed a plan for full-scale implementation with a timeline and benchmarks; and provided supports for individual institutions to prepare them for mathematics pathways implementation. Some states developed student learning outcomes for mathematics pathways courses, a key ingredient for enhancing both their transferability and their program applicability. Some enhanced the transferability of mathematics pathways courses in additional ways and reached a statewide consensus on the programs of study to which key mathematics courses should apply.

The accomplishments of the MPC project are noteworthy because they were achieved in states with both centralized and decentralized higher education contexts, largely without legislation. Instead, state task forces engaged in a process of faculty and institutional engagement, where representatives from two- and four-year colleges made or approved key decisions that contributed to the vision, resources, and guidance for implementing mathematics pathways statewide. System leaders provided support during this decision-making process and, in some contexts, deployed policy strategically to reduce barriers to adoption. As this report shows, each state approached this work differently. The presence of a centralized department of higher education helped in securing institutional commitments, identifying policy levers to facilitate implementation, and convening stakeholders from across the two- and four-year sectors. However, the work of gathering input from stakeholder groups, building consensus, and communicating the vision for mathematics pathways was similar across contexts.

To successfully implement a top-down/bottom-up approach to statewide reform, change agents must navigate tensions between authority and engagement as they determine how to reach decisions on key questions of policy and implementation. In the MPC project, the task forces, primarily composed of and led by mathematics faculty, could not accomplish all project tasks alone. The complexity of arranging cross-institutional and cross-sector conversations with non-mathematics department chairs, stakeholders with decision-making authority over transfer policy, advisors, and institutional leaders meant that progress was slower than some task force members would have liked. In addition, the MPC project represented just one of many student success initiatives underway in these states. Individual institutions were engaged in myriad reforms, some of which required coordination with mathematics pathways efforts (e.g., new developmental placement processes) and some of which competed for faculty energy and attention (e.g., course redesigns in the upper division mathematics curriculum). Yet concurrent reform efforts also provided opportunities for resource sharing and enhanced momentum. By the project's conclusion, all six states had strong coordination efforts between their mathematics pathways task force and one or more other ongoing initiatives, including statewide transfer efforts, longstanding developmental mathematics reform infrastructure, corequisite reforms, and/or guided pathways support structures. (See Bickerstaff et al., 2018, for a discussion of coordination between the MPC project and other reforms.)

The varied contexts of the states involved in the MPC project provided a test case for working across governance structures and higher education sectors and differing approaches to leveraging policy and legislation. The ultimate results of these efforts are unknown; by design, institutions were beginning their mathematics pathways implementation at the project's conclusion. Future external evaluations should investigate the extent to which institutions were enabled to implement mathematics pathways successfully and with fidelity to the task force's vision. The Dana Center is continuing to collect data on these efforts to track changes in student outcomes.[12]

The top-down/bottom-up approach provides an alternative framework for large-scale change in higher education that is attentive to the critical role played by faculty and other institutional stakeholders. The Dana Center set the ambitious goal of making mathematics pathways "normative practice" in all public postsecondary institutions in participating states but allowed faculty leaders and their system-level colleagues to make key decisions about the structures and timeline for achieving that goal. This customization allowed six diverse states to make significant progress toward implementing a common vision of mathematics pathways in two- and four-year institutions statewide, bringing them closer to the goal of large-scale improvements in student retention, learning, and success.

Endnotes

1. For a description of other mathematics pathways models, see Ganga and Mazzariello (2018).
2. College algebra has historically served as a terminal mathematics course, but the Mathematical Association of America and other disciplinary organizations have called for reforms to college algebra to ensure it adequately prepares students entering STEM fields for advanced mathematics (Saxe & Braddy, 2015).
3. Some states included a mathematics faculty representative from every public institution, whereas others did not but ensured that all systems and sectors were represented. A few states also included other stakeholders, such as K–12 system representatives.
4. For more information about task force activities and accomplishments in MPC states and other states, see The University of Texas at Austin, Charles A. Dana Center (2018b).
5. See Moussa and Bickerstaff (2019) for more on this institutional survey, including selected items and additional findings.
6. These figures are derived from the results of the Community College Research Center's student enrollments and outcomes survey administered to institutions in five states in fall 2017. For more information, see the appendix.
7. Institutions may only offer precalculus instead of college algebra. Some colleges only offer statistics as a more advanced course or may offer an introductory version in departments other than mathematics.
8. Of the three states that did not establish common learning outcomes during the project, one state already had common learning outcomes for its mathematics pathways courses before the project began. Two other states with common course numbering used the working group structure to review and revise course descriptions and discuss student learning outcomes but did not ultimately enact common learning outcomes.
9. Massachusetts joined the MPC project later and did not reach Phase 3 by the project's conclusion. One state engaged institutions implementing mathematics pathways but did not secure written commitments from them.
10. The full project description is available on the National Science Foundation's website: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1821545.
11. See endnote 9.
12. With support from the Dana Center, state task force leaders created a plan to evaluate the impact of the project on institutions and students after the project's completion.

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Appendix

This report draws on four major sources of data. First, the Dana Center administered a state readiness assessment to project leaders in each state at three points during the project: January 2016, September 2016, and October 2017. The assessment contained 31 indicators of successful mathematics pathways implementation. State leaders provided a self-assessment for each indicator on a 4-point scale ranging from 1 (not at this time) to 4 (well-developed). The Dana Center shared the states' responses on these self-assessments with the Community College Research Center (CCRC). Mean scores for the first and final self-assessments on selected items relevant to this report are provided in Appendix Table 1.

Second, to understand the extent to which colleges were already offering courses and pathways in concert with the DCMP principles, as well as rates of student enrollment and success in mathematics courses, CCRC administered two online surveys to all public two- and four-year institutions in fall 2017 (one year before institutions were to begin their implementation). Based on the states' plans for mathematics pathways implementation, we focused survey questions on seven mathematics courses: intermediate algebra, introductory statistics, college algebra, quantitative reasoning, mathematics for education majors, mathematics for business majors, and precalculus. For each course, respondents were asked to provide information on the number of sections offered, the number of credit hours, whether it has college-level or developmental prerequisites, and whether a corequisite option is available. With support from the Dana Center, the survey was distributed to institutional leaders in five states. The sixth state employed a consultant to gather this information from college websites. In total, data were collected from 93 public two-year and 60 public four-year institutions, with response rates of 92% and 90%, respectively. Findings from these surveys were shared with the Dana Center and with states to aid with project planning.

Third, to gather more detailed information on state and institution project activities and stakeholder perceptions of those activities, CCRC conducted 69 semi-structured interviews with members of the state task forces and other key stakeholders, including Dana Center staff. These interviews were conducted by telephone in spring 2017 and spring 2018. Interviews were audio-recorded with respondents' consent, transcribed using a third-party service, and organized and coded using Dedoose, an application for analyzing qualitative data. Interviews were coded using a standardized coding scheme based on our main research questions and emergent themes identified during the interviews. Sample codes include "accomplishments," "buy-in," "challenges," "course content and student learning objectives," "developmental mathematics," "funding and resources," "goals of participation," "task force activities," and "transferability and applicability."

Finally, CCRC observed several project activities, including two convenings of members from each state task force in fall 2016 and fall 2018, a mathematics pathways workshop for institutions and a training for Dana Center consultants in 2017, and several calls and webinars with state leaders throughout the project. In addition, CCRC used state-produced reports, publications, and project deliverables to understand how states were engaging in project activities and how they were progressing toward project goals.

Appendix Table 1.

Mean Scores in State Readiness Assessments, Selected Items

Scale: 1 = Not at this time; 2 = Emerging; 3 = In progress; 4 = Well-developed

	ROUND 1[a]	ROUND 3
Leadership and Commitment		
Governor, state agency, or other statewide body has articulated a commitment to math pathways (e.g., report, statement).	3	3.7
A mathematics faculty task force or committee exists to lead the development of statewide math pathways.	2.8	3.7
There is an established hub for math pathways with dedicated staff time and allocated resources.	2.7	2.7
Structured, regular communication vehicles or networks coordinate state leadership and math leadership broadly to advance strategic plans.	2.8	3.3
A commitment to a statewide scale of math pathways is clearly articulated and broadly supported by key stakeholders.	3	3
Multiple Math Pathways for Gateway and Developmental Courses		
Data are used to assess math needs of students in the state.	2.7	2.7
Two or more math pathways are established with gateway courses that meet the needs of the full range of academic and workforce programs (at a minimum, algebraically intensive programs and programs that are not algebraically intensive).	2.3	3.5
Statewide, there are designated courses or policies that allow options for developmental mathematics courses or interventions that are aligned to gateway courses (i.e., algebraically intensive developmental content is not used for non-algebraically intensive gateway courses).	2.7	2.7
Institutional and state policies enable accelerated developmental education using one-semester corequisite or two-semester course pathway models.	3.3	3
College readiness is not defined by completion of intermediate algebra in state or institutional policy.	3.7	3
Transfer and Applicability		
Learning outcomes are established for multiple gateway math courses to ensure transferability statewide.	1.7	3
Common course numbers are used.	1.8	2.8
Multiple gateway math courses are included in general education/core curriculum.	3.2	3.8
A statewide framework for aligning math pathways with broad program areas (meta-majors) is developed and understood by stakeholders.	1.7	2.7
Institutional degree program requirements reflect statewide framework aligning mathematics pathways and programs of study.	1.8	2.7
Faculty Professional Learning		
The state provides opportunities and resources for faculty professional development to implement math pathways.	2.3	2.7

Note. Items were selected based on their relevance to the project goals and activities described in this report. See the full assessment at https://dcmathpathways.org/resources/state-readiness-assessment.

[a] First-round assessments were administered in January 2016. Massachusetts's first assessment was administered in October 2016 because the state joined the MPC project at a later date; however, we include this assessment in the January 2016 calculations to reflect the baseline data of all six states. Third-round assessments were administered in October 2017.

CCRC COMMUNITY COLLEGE RESEARCH CENTER

TEACHERS COLLEGE, COLUMBIA UNIVERSITY

Community College Research Center
Teachers College, Columbia University
525 West 120th Street, Box 174
New York, New York 10027
212.678.3091
ccrc@columbia.edu
@CommunityCCRC
ccrc.tc.columbia.edu