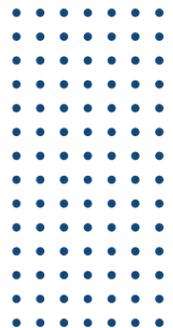


Moving Mathematical Mountains:

A Decade of Educator-Led Change to Make Math a Gateway to Success for All Students



Executive Summary

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The last decade has marked a historic turning point in higher education and a watershed moment for creating more student-centered and equity-focused education opportunities. For years, the standard developmental math sequence has stopped countless students from advancing academically—creating a gatekeeper to college success and completion. In 2010, we established the

Carnegie Math Pathways Networked Improvement Community, bringing together educators and researchers and using an improvement science framework to remake the entry-level college math system into a more equitable and empowering gateway to college success and completion for every student.

Over the last decade, Carnegie Math Pathways has helped propel tens of thousands of students to and through gateway college mathematics, increasing outcomes by an average of three- and four-fold compared to those of traditional math sequences. These increases hold across sex, race, and ethnicity, with students experiencing higher confidence in themselves as math learners and doers and higher graduation rates compared to students in standard remedial math courses. Our programs have helped colleges and systems transform their math offerings and advance their college completion goals. In the process, we have amassed a community of over 1,000 educators, who, through their commitment to promoting a more equitable approach to math learning and teaching, have driven the creation and continuous improvement of innovative course solutions and instructional resources.

The collective efforts of the Pathways Network have helped shape a national math pathways movement, prompting institutions to critically rethink their entry-level and foundational math offerings and expanding the body of evidence proving the effectiveness of corequisites and how to support their successful implementation. This report highlights the impact and key learnings from over 10 years of Carnegie Math Pathways implementation.

A handwritten signature in black ink that reads "Karon Klipple".

Karon Klipple
Executive Director
Carnegie Math Pathways

Introduction: A new vision for mathematics



Moving mathematical mountains means increasing opportunities for all students to access and succeed in college-level math. Working alongside educators, we've done this by:

- *rethinking the structure of entry-level mathematics*
- *changing the classroom learning experience*
- *creating an evidence base that's moved the field to corequisites*

ALL STUDENTS DESERVE OPPORTUNITIES to engage in mathematics learning that is meaningful to their lives and relevant to their academic and career aspirations. And they deserve college courses that put them on the best possible path to success. Evidence shows that students are not well served by multiple levels of remedial prerequisites but rather, that with the right supports, they can be successful directly in college-level courses. Yet, few students have had this opportunity. In fact, remedial math education has, for years, been a source of inequity in and the single largest barrier to college completion.

A 2010 study published by the Community College Research Center (CCRC) put in stark relief the widespread inequities and profoundly negative effects of the remedial math system in higher education, something long known first hand by instructors. At the time of the study, over 500,000 students annually were failing developmental mathematics,¹ preventing them from achieving their college and career goals. This system was particularly disadvantageous to Black, Latinx, Indigenous, first-generation students, and students experiencing poverty.² Students in developmental math were paying a steep price in time,

money, and morale in non-credit-bearing courses. This systemic barrier to students has cost our educational institutions investment dollars, our national workforce valuable human capital, and our communities and country more informed and empowered citizens.

That same year, we brought together researchers and practitioners to create the Carnegie Math Pathways Networked Improvement Community. Collectively, we set out to radically re-envision entry-level college mathematics by examining breakdowns in the status quo system—from course structures and placement practices to what happens in the classroom. **We aimed to create a more equitable system that engaged students in math relevant to their lives and academic goals and made math a gateway to college completion for all students.** With insights from educators' experiences in the classroom and at their institutions, the expertise of researchers across a broad set of disciplines, and an improvement science framework focused on design, testing, and continuous refinement, we were able to build a holistic approach that reshaped entry-level math education and is transforming the educational journeys of tens of thousands of students.

The result was Quantway and Statway—a suite of quantitative and statistical reasoning courses, initially designed as two-term pathways and then further developed into single-term corequisites. Quantway and Statway are designed with:

- **contextualized curricula** that explicitly connect math to the real world and includes language and literacy supports to help students engage with the authentic contexts and express their reasoning
- **a research-based pedagogy** designed to create a more welcoming and productive learning environment through collaborative, discovery-based instruction and
- **thoughtfully embedded social emotional learning routines** to strengthen confidence, nurture a sense of belonging, and encourage persistence.

Alongside these courses, our network created robust resources to help instructors facilitate this kind of classroom experience and help administrative leaders establish institutional structures to support this new approach.

These comprehensive solutions have given institutions new math options that provide more meaningful and equitable paths for students to excel in math, graduate on time, and go on to achieve their career goals. Today, students enrolled in Pathways courses are succeeding at 3-4 times the rate of their peers in traditional developmental math sequences, and in half the time or less.

These success rates have held year after year, across sex, race, and ethnicity, even as Pathways course enrollments have grown 10 fold. And longitudinal studies show Pathways students graduating at twice the rate of their peers who enroll in traditional remedial math programs.

Quantway and Statway outcomes have demonstrated that a new approach to math education is not only possible but essential. No longer is college algebra seen as the only path for students regardless of interest or major. Instead, statistics and quantitative reasoning are recognized as offering rigorous, and more relevant learning for students in a wide range of programs and certificates. And multiple levels of remediation are not needed. With the right supports, students can succeed in college-level math as soon as they enroll in college.

These results have catalyzed a national movement uniting educators to transform students' math learning experience. Not only are expanded math options increasingly the norm, but we've helped educators make math learning and teaching more inclusive and engaging. And by challenging the status quo system of remedial math, Carnegie Math Pathways has helped propel the field toward corequisite models that enable students to enroll directly into college-level math while receiving additional support to address learning gaps. Today, corequisites are being used at scale in 24 states, and many more are beginning adoption.³ Combined with multiple measures placement practices, corequisites and math pathways are helping significantly more students access and succeed in gateway mathematics.

This report highlights the impact and innovations generated by Carnegie Math Pathways across the last decade and offers key learnings about the conditions needed to make effective math opportunities available to many more students.

3-4X

Carnegie Math Pathways students succeed at 3-4X the rate of students in traditional developmental math.

.....

1/2 THE TIME

Pathways students earn their college math credit in half the time or less than students in traditional remedial math.

.....

10X

Pathways course enrollments have increased 10-fold, with success rates holding year after year, across sex, race, and ethnicity.

.....

2X

Pathways students graduate at twice the rate of their peers in traditional remedial math programs.

Carnegie Math Pathways Quantway and Statway Solutions

Based on a set of learning outcomes established with guidance from the major mathematical and statistical societies, our network designed rigorous quantitative and statistical reasoning math pathways. These course solutions are designed to increase success in credit-bearing college-level math within 1-2 terms for all students, regardless of placement level.

Quantway

Quantway is a suite of quantitative reasoning courses designed to enhance students' conceptual mathematical understanding through applications in civics, personal finance, health, and other real-world contexts and strengthen their confidence to apply quantitative reasoning in their personal and professional lives.

Quantway Corequisite - our primary college-level quantitative reasoning course incorporates corequisite support to enable students to achieve college credit in a single term.

Quantway College - our college-level quantitative reasoning course

Quantway Core - a quantitative reasoning course designed to build foundation skills for students in high school and at technical colleges

Statway

Statway is a suite of courses that provide students with the statistics skills needed for the 21st-century to confidently apply data analysis and reasoning to their lives and careers.

Statway Corequisite - our primary college-level statistical reasoning course incorporates corequisite support to enable students to achieve college credit in a single term.

Statway College - our college-level statistical reasoning course

Statway Pathway - a year-long statistical reasoning course for K12 and dual enrollment programs



A decade of impact on math learning and teaching

QUANTWAY AND STATWAY SOLUTIONS, and the networked improvement community we've formed to develop and continuously improve them, have made a profound impact on students and educators since our founding in 2010.

Beyond dramatically improving student success rates, the Pathways approach has given educators new, evidence-based strategies to engage students in their learning and also positively impacted the way many students perceive themselves as math learners.



Our first 10 years by the numbers

In their first 10 years, Quantway and Statway have demonstrated remarkable success. Unlike other educational reform efforts, outcomes in Quantway and Statway have sustained and even increased as the programs have expanded to more students, faculty, and institutions. Here's a look at the numbers.

81,794

Students Served

1,159

Faculty Served

140

Institutions Served

Quantway and Statway Average Success Rates

Quantway Corequisite

75%

21% Baseline

2017-18 to 2020-21

Quantway College

68%

2012-13 to 2020-21

Quantway Core

62%

21% Baseline

2017-2018 to 2020-21

Statway Corequisite

61%

15% Baseline

2018-19 to 2020-21

Statway College

75%

2018-19 to 2020-21

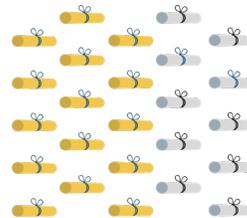
Statway Pathway

53%

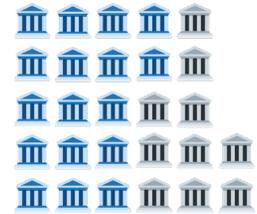
15% Baseline

2017-18 to 2020-21

Carnegie Math Pathways students graduate, transfer, and earn 4-year degrees at significantly higher rates than their matched peers. In one study of Statway students, we found that:



For every 10 students in traditional courses, more than **15 Statway students** earn their two-year degree or credential.

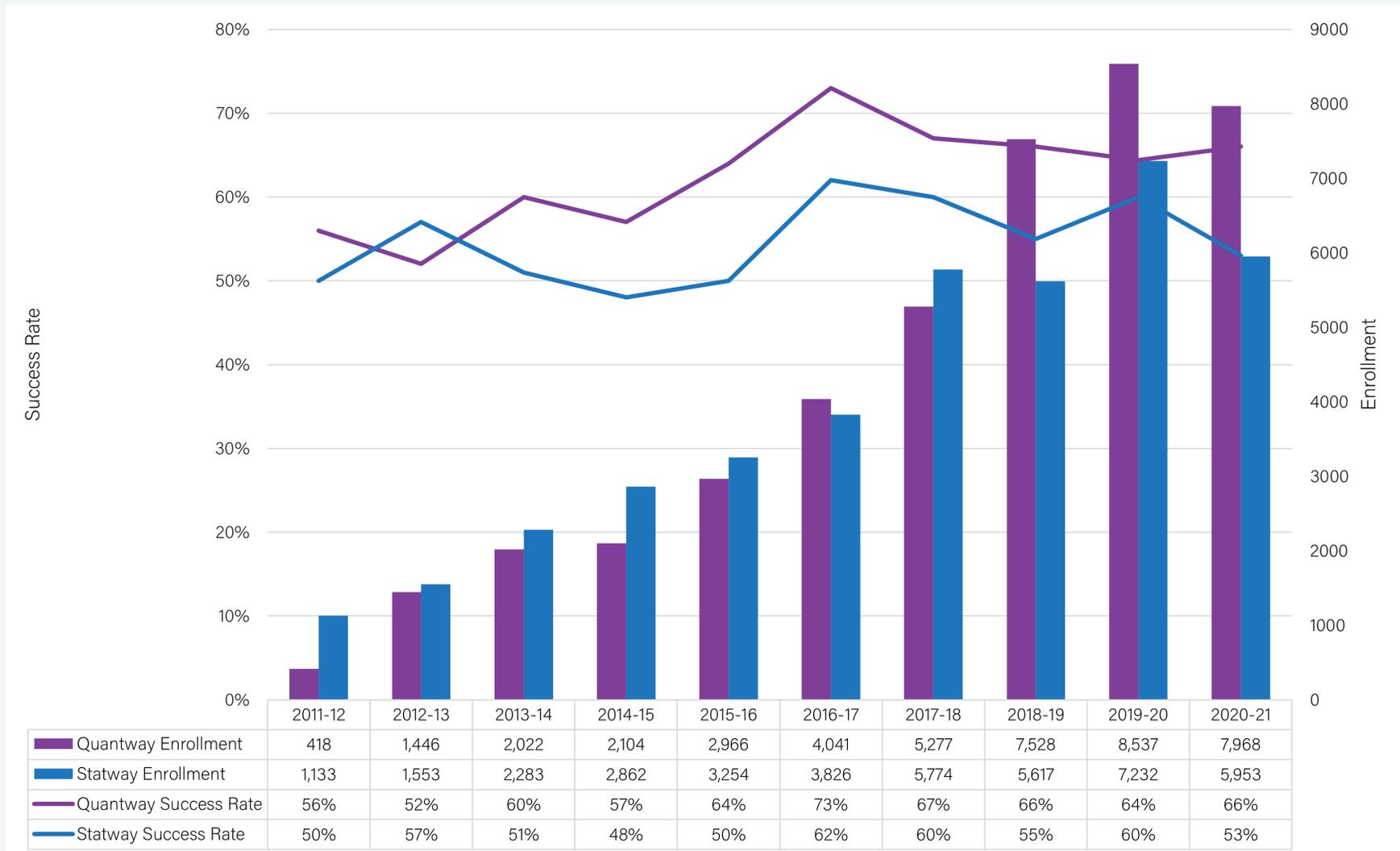


For every 10 traditional students, **17 Statway students** transfer to a four-year institution.



For every 10 traditional students, more than **22 Statway students** earn their four-year degree.

Quantway and Statway Success Rates Over Time



Pathways courses have not only dramatically improved student outcomes—they have also enhanced faculty practice and strengthened students' confidence and self-efficacy as math learners.

Enriching the faculty teaching experience

Breaking from the lecture style and drill and kill practice of traditional math classes, Pathways educators use an active learning approach to create a more welcoming and engaging learning environment for students.

In Pathways classes, students collaborate around rich problems that enable them to productively struggle together, build connections, and exercise and strengthen their skills.⁴ With this approach instructors gain deeper understanding into their students' thinking and learning and stronger connections with their students that help support the learning process.

Through structured peer-led professional development and mentorship, educators learn how to use active and collaborative

Changing the learning experience to help more students thrive—an educators' journey

Like many other math educators, George Hurlburt, faculty at SUNY Corning Community College, witnessed his students struggling in isolation to understand and do math. But through teaching Quantway and the support provided by Carnegie Math Pathways, he's gained the skills to create a different kind of learning experience for his students—one that's generating more engagement and greater success.

With Quantway's collaborative learning model, Hurlburt has reoriented his in-person and online classes from a lecture-based environment to one where students take charge of their own learning by collaborating on contextualized math problems together. Working in groups, his students draw on their strengths and communication skills to find a solution as he facilitates their learning in a supporting rather than a leading role. By not immediately jumping in when he hears his students struggling, for example, he provides them with the opportunity to arrive at an answer through their own problem-solving and teamwork abilities.

"When students are directing their own learning, they learn much better than when I'm standing in front of the classroom and talking or if I'm just posting a video for an online class."

practices that build students' agency and ownership of their learning. Here are just a few reflections from Pathways educators on how this approach has impacted their practice:

- *"I know what [my students] know better, not just by their tests, but by my interactions with them in the classroom."*
- *"All together it has helped me gain perspective on students' math needs and how to engage and connect with students."*
- *"One of the biggest impacts of teaching Quantway that has infected all of my other classes is that I can't just jump into the content like I used to. It's become very apparent that the content is there, but those underlying skills are what really make students succeed in the end: the sense of belonging, the sense of being part of a team, and we're in this together. That's very important to the success of my other classes now too."*



This change has shown Hurlburt that his students are learning just as effectively, or even more so, with this new approach and says it is especially beneficial to students who are learning at a distance. His online students' success rates are just as high as the rates of those students in his in-person courses.

Hurlburt and his students believe that the collaborative approach to the course has played a key role in their success. "When students are directing their own learning, they learn much better than when I'm standing in front of the classroom and talking or if I'm just posting a video for an online class."

Moreover, the collaborative learning model has allowed Hurlburt to get to know his students better. As students work together through the math problems, they reveal more about themselves and form bonds with their peers and the instructor. That connection has been so critical to keeping students motivated in the course, and it was largely missing in Hurlburt's previous courses.

Reflecting on the impact of this changed instructional approach, Hurlburt reports, "I've seen how when students figure things out for themselves rather than being given the answer, they become more confident in their ability to learn and master the content. And seeing that has really motivated me to change the way I teach all my classes, in-person and online." ♦

Transforming students' mindsets and attitudes towards mathematics

The active, collaborative approach and social emotional learning in Carnegie Math Pathways courses have helped students drastically improve their relationship with math. Designed to target non-cognitive factors that impact student engagement, persistence, and ultimately their success, our Productive Persistence supports help instructors create learning environments that reduce student anxiety, strengthen their confidence, and foster in students a sense of belonging in the math classroom and in college. A decade's worth of data about our Productive Persistence interventions shows that attending to such factors positively improves engagement and success.

Pathways students complete surveys at the beginning of the course that measure these factors. The results show that students

often enter the course with internalized beliefs that they will not succeed, do not belong, and cannot relate to the material taught in math courses. For example, over 60% of students in a 2016 study agreed with the following statement about the fixed nature of mathematics intelligence: "Being a math person or not is something you really can't change. Some people are good at math and other people aren't."⁵

Through the use of targeted Productive Persistence activities and routines, faculty are able to create learning environments that shift these beliefs. In fact, by week 4 of Pathways courses, significantly more students report being in a growth mindset about mathematics instead of a fixed mindset, experiencing less anxiety related to mathematics, feeling more comfortable asking the instructor questions, and feeling that the instructor cares about them.⁶ And it has been shown that these changed mindsets and behaviors directly contribute to greater success in the course.

Offering more than just math credit, Statway helps build skills and confidence for success in life

When Candice Valdez enrolled in Statway at Saginaw Chippewa Tribal College at the beginning of the spring 2021 term, she was deeply skeptical about whether she could succeed in the course. Memories of her struggles with math classes in middle and high school had ingrained in her a deep fear for the subject.

Valdez, a 46 year old mother of two working two jobs, had entered college with the goal to gain more economic opportunity and stability and to show her kids that it's never too late to get an education. But because of her anxiety, she had avoided taking the math she needed for her degree and even contemplated dropping out of college entirely.

"I didn't realize how much math was involved with being a slot supervisor. But it's quite a bit. I'm actually using math every day."

With the support and encouragement of her professor, Valdez enrolled in SCTC's Statway course and found herself succeeding at math. Reflecting on that time, Valdez says she was surprised to find that she also really enjoyed the course.



The group structure as well as the pre-work activities helped her feel comfortable and prepared in the class, while the social emotional supports and learning strategies she developed helped her gain confidence in her ability to successfully do math. "I've learned about just slowing down and going through a math problem, going through and figuring out what I needed to do. And then that's how I get my answer."

And it's benefited her professionally at her job at the local casino. "I didn't realize how much math was involved with being a slot supervisor. But it's quite a bit. I'm actually using math every day." While Candice still gets nervous when facing math problems, she's excited when things she learned in Statway come up in her daily life. She's realized that the more she uses her math skills, the more comfortable she becomes with applying them to situations in her day-to-day life.

The supportive math learning experience Valdez found in her Statway course helped transform how she views and approaches math in her life. With enhanced confidence in her abilities, and her math requirement satisfied, Valdez is continuing on her education journey toward her goals. ♦

Building an educator network to create and sustain new paths to success

OPERATING AS A NETWORKED IMPROVEMENT COMMUNITY IS what defines Carnegie Math Pathways and what has made our work successful. Working collaboratively with practitioners who bring on-the-ground experience and knowledge of their students and communities, we've co-designed, tested, and improved innovations that are more impactful and more aligned with student and educator needs than if we had designed them on our own.

Three of the most consequential areas of educator collaboration across our network are curriculum development, peer mentorship and professional support, and network leadership.

Rethinking curriculum with educator insight

Faculty play a central role in the design, development, and ongoing improvement of the Quantway and Statway curricula and instructional resources. What our network has developed differs drastically from the traditional approach to college math learning—rote, procedural practice with drill-and-kill exercises—which research shows isn't producing anything near positive results for most students. Instead, the Pathways community has designed and continues to refine curricula that engage students in real-world contexts related to their area of study or life experiences.

At scale, the Pathways curriculum has several important benefits that make learning more equitable. For one, the common curriculum helps faculty provide more consistent experiences across classes and institutions. This shared curriculum removes a source of variability, making it possible to examine variations in outcomes across classes and institutions and identify and develop needed improvements to increase student achievement.

In addition, by having faculty involved in curriculum development, lessons are better contextualized to reflect their students and communities. This helps students see themselves in the lessons and how math is directly relevant to their lives.



Moving mathematical mountains means empowering and engaging educators. In the Carnegie Math Pathways Network, educators lead curriculum design, professional development, and governance of our improvement agenda.

Our curriculum-focused faculty teams have made a number of improvements to the curricula and instructional supports, helping educators to more effectively deliver accelerated math pathways and meet the needs of diverse students. Improvements include:

- lessons focused on contemporary social issues, cultural contexts relevant to Native communities, and fields of study such as applied health care, environmental technology, and information technology.
- supplemental lessons that support a path to calculus from Quantway and Statway.
- online versions of Quantway and Statway designed to support collaboration and build a sense of belonging among students.

Creating an empowering math learning experience by centering Native students in the curriculum

Tribal College and Universities (TCUs) serve a diverse body of students, with more than half of the 573 federally recognized tribes represented. Created by their own tribal governments to provide higher education opportunities to Native communities in the U.S., these institutions are focused on supporting students with holistic education programs uniquely grounded in local Native culture, values, and traditions.

Beginning in 2017, Carnegie Math Pathways formed a network with TCU partners to introduce and implement quantitative and statistical reasoning pathways at their institutions. For these programs to be sustainable and successful at TCUs, it was critical for the curricula to be relevant to students and aligned with the values and practices of the partnering institutions. That required understanding the communities and the students served.

“Students know that they’re not represented in the textbooks, and they’ve known it all along. But until they see themselves represented, they don’t realize what an impact that has.”

Working with a dedicated group of TCU math educators, we launched a collaborative effort to redesign the Quantway and Statway lessons to more meaningfully connect to Native students’ lives and to the values of their communities and institutions.

With insights from students, community resources, and educators, the TCU curriculum committee has created a suite of new lessons that explore Quantway and Statway math concepts through water rights, measuring plant and animal life in local ecosystems, blood quantum laws, the buffalo population, and more.

Connecting math to things of value in students’ lives is powerful for learning. It reveals to students how math can empower them and their communities. And by reflecting their communities, this effort is enhancing a sense of belonging in the math classroom.

These lessons, which are being shared not only among the TCUs but also available for use throughout the Carnegie Math Pathways



network, raise the visibility and representation of Native students, their communities, and their history in math curriculum. “Students know that they’re not represented in the textbooks, and they’ve known it all along,” Jennifer Morris, Quantway instructor at the College of Menominee Nation in Wisconsin, said, “but until they see themselves represented, they don’t realize what an impact that has.”

By creating inclusive math lessons that are accessible and recognizable to their students, TCU math educators are not only supporting students in seeing how they are capable of excelling in complex, rigorous math. They are helping to break down traditional barriers in math education and empowering Native students with knowledge and confidence to use math in ways meaningful to their lives. ♦



Professional learning and support within a community of peers

We believe faculty are key to successfully transforming the math learning experience. To support instructors in their practice, our peer-based professional development program provides meaningful learning opportunities while also connecting them with a rich educator community.

Instructors begin with training led by experienced Pathways instructors that orients them to the Pathways approach and are then paired with a peer mentor to support them in their first years of teaching. Pathways mentors bring not only their expertise in teaching Quantway and/or Statway, but they also serve as a touchpoint for each new instructor to our broader network of educators.

Within the network, there are research and development teams focused on developing and improving Pathways curriculum and faculty supports. Instructors can also choose to take part on these teams, which bring together educators across campuses to share ideas, build specialized expertise, and develop resources in order to continuously improve the Pathways.

Connecting like-minded instructors across institutions and providing applied professional learning opportunities has been critical to helping Pathways educators shift their instructional paradigm and create a more inclusive and supportive math learning environment on campuses across the country.

Carnegie National Faculty: A shared governance model for reform

Forming and sustaining a system of shared leadership for the Pathways has been a central goal since our inception. We believe that giving educators a place at the table is what makes our network thrive and gives us the ability to flexibly meet the needs of faculty and students.

Early in the history of Carnegie Math Pathways, we established the Carnegie National Faculty (CNF)—a select group of educators with exemplary student outcomes, a strong commitment to the improvement of Pathways programs, and demonstrated leadership within our network—to represent the interests and perspectives of educators in the network. Working with Carnegie Math Pathways researchers and leadership, this body gives educators a strong voice in the network's strategic direction, including where the network invests its efforts for improvement.

"The Pathways network has given me an opportunity not only to contribute, but to learn so much as well. And I think learning from each other and developing new practices and testing new practices improved my teaching amazingly. I'm implementing things I've learned in the network in other classes and having great success."

Sandy DeSouza, Statway Faculty

Over the years, the group has codified our improvement priorities and co-led our development efforts, most specifically improving the faculty professional development program, expanding the breadth of Productive Persistence interventions, and redesigning the student online learning experience. They have also helped hone our research agenda to focus on expanding opportunities for online learners, deepening our understanding of and ability to address inequities in student outcomes by race and ethnicity, and strengthening the pathway from high school to college. The input, perspective, and guidance of this collective body enhance all that we do.



Leading the field with key innovations

OVER THE LAST DECADE, our network has brought innovative solutions to scale, while continuing to test and refine new ideas that push the boundaries of what's possible in math education. Here are some of the ways Carnegie Math Pathways has moved the field forward.

Introducing new pathways to college math success

Our network challenged the notion of a single path for mathematics success. Recognizing the inequities of the status quo and the needs of the 21st-century workforce and society, our network designed new math pathways focused on building statistical and quantitative reasoning that are aligned to recommendations from the national mathematical and statistical associations.

Quantway and Statway pushed the field to reconsider what best prepares students to be college and career-ready. Carnegie Math Pathways has developed a rich learning model that makes math more accessible and meaningful to students and helps them build a more productive relationship with mathematics useful to their lives and career paths.

Success is possible for all students in college-level math with the appropriate supports

Quantway and Statway are built upon the idea that with the right supports, students can be successful in college-level mathematics as soon as they start college. Data from our first 10 years shows that this holds up. Pathways students perform just as well with college-level mathematics content regardless of whether they were assessed as needing intermediate algebra, elementary algebra, or even pre-algebra. This demonstrates that sequences of developmental courses are not only unnecessary but also harmful in terms of the undue burden of additional cost, stress, and time these courses place on students. This evidence has helped spark the move to corequisite remediation, now in place in 24 states⁷ and growing.

Supporting the whole learner

Increasing student success requires acknowledging behaviors, attitudes, and feelings that students may experience in relation to mathematics. For many students, math elicits a variety of negative

reactions—from deep anxiety to doubts over its application to real life, to a sense that math is an innate skill that they just don't have. Others, whose previous experiences in math or school were not welcoming, may question their place in the classroom.

Until recently, these non-cognitive factors were given little attention in terms of their impact on the learning process. Yet, research shows that supporting students' social emotional well-being has a transformational effect on their engagement and directly impacts their success.⁸

Working with leading education and social psychologists, we developed Productive Persistence supports that positively affect how students see themselves and their abilities as math learners.⁹ These supports are embedded into the curriculum and pedagogy to help build confidence, foster a sense of belonging, and promote effective learning strategies.

Reimagining online learning

Most online courses offer a largely solitary learning experience—one that hasn't produced widespread success. We wanted to change that. We aspired to create an online learning environment that connects and engages students collaboratively.

Together with educators and education technology experts, we built online versions of Quantway and Statway. Building on the evidence-based features of our in-person courses, we developed an innovative platform that integrates both adaptive learning technology for individualized learning and video conferencing for small group collaboration with structured learning activities.

The platform incorporates design principles proven to create a collaborative environment that engages students in deep learning while fostering a sense of community and belonging.

Results from nearly 10,000 students at 51 institutions show that students in online Carnegie Math Pathways courses succeed at the same high rate as students in the Pathways in-person courses—three to four times the rate of students in traditional math sequences.

Strengthening pathways between K-12 and college

Roughly halfway into our decade of work, Carnegie Math Pathways began partnering with K-12 and postsecondary leaders to build a better pathway between high schools and colleges that would eliminate the need for remediation and ensure that students graduate from high school prepared to thrive in college-level mathematics.

The results are new promising dual enrollment and 12th-grade college readiness math pathways programs. We've partnered with several schools across the country to implement dual enrollment programs. One example is Madison Area Technical College in Wisconsin. Madison College launched a dual enrollment program with their high school partners that gives students access to Quantway as an alternative to elementary algebra and earns students credit toward Madison's applied programs. We've also partnered with K12 school districts to establish math readiness programs at the middle and high school levels. In Rhode Island, the Department of Education partnered with local colleges and Carnegie Math Pathways to design high school and college math readiness programs for incoming ninth and twelfth graders.

With states beginning to mandate fourth-year high school math and as higher education institutions look to dual enrollment as a way to increase enrollment, math pathways provide more equitable learning opportunities to get students to and through college. Early results show that there's promise in bringing these evidence-based options to high schools.

Madison's dual enrollment program (launched in fall 2020 during the COVID-19 pandemic) served 281 students. Despite the challenges of having to work with students remotely, instructors reported that students in their courses were engaging productively with each other and the curriculum and felt the course was strengthening students' reading and math skills. Meanwhile, in Rhode Island, students in the high school math readiness course improved their post-math test scores by an average of 15 percentage points, and those in the college-readiness course improved their SAT score by an average of 55 points. Growth was particularly pronounced for the college-readiness students who began the course with below-average skills in math and who increased their SAT score by 100 points.



A college student success strategy that begins in high school: Quantway dual enrollment

Beginning in 2014, Madison Area Technical College (Madison College) introduced a math reasoning path using Quantway Core to boost outcomes and help more students advance out of developmental level math. The new course provided an alternative as rigorous as their algebra-based developmental sequence but that better aligned to many of Madison College's applied programs and other non-STEM majors. And it also shortened students' path to college level math. The results have been striking. With Quantway Core, Madison College saw success rates increase initially from an average of 17% in one year to 62% in one term and they have grown over time to a current average of 74%, even as enrollments have expanded.*

* Baseline data is based on success rates for Liberal Arts students who complete Madison College's Elementary Algebra and Intermediate Algebra sequence in one year.



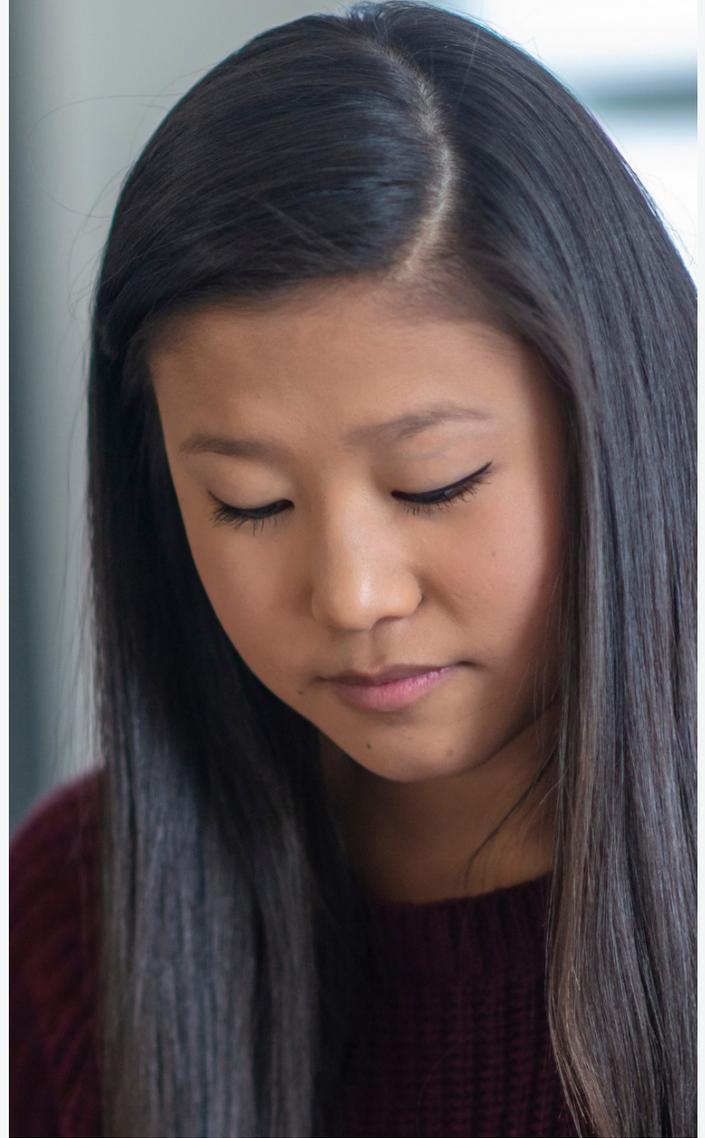
Yet, while the course was benefiting students at the college, faculty in the Madison math department were convinced there was more they could do to support students before they arrived at campus. Each year, significant numbers of new students entering from high school were not eligible to enroll in Madison College's college-level math courses and were instead being directed to enroll in prerequisite courses. That outcome was costing these students extra time and money, and in some cases, thwarting their entire academic aspirations.

Madison's math faculty knew that to increase student success at their college, they needed to work with local high schools to provide more paths to college-level math readiness. They saw an opportunity to do this with Quantway Core. Working with their dean, their college K-12 partnership office, and local high school instructors, Madison faculty introduced a math reasoning dual enrollment course for high school students using Quantway Core. Much like at the college, this course would offer students a new, alternative option to algebra to meet their high school math requirement and provide, in many cases, more appropriate and meaningful math preparation to their academic and career interests. Students who participated would earn college credit toward many of Madison's applied technical programs, and, for those who wished to pursue academic programs, it would ensure they could matriculate ready for college-level quantitative reasoning.

Quantway Core offers Madison district high school students an alternative to algebra to meet their high school math requirement and in many cases, provides more appropriate and meaningful math preparation for their studies and career.

The program launched in fall 2020, in the midst of the COVID-19 pandemic, with 10 high school teachers from eight schools, and now aims to expand to all 40 high schools in the district. In its first year, the program served 281 students with an average success rate of 45%, only slightly lower than the average success rate for Madison's dual enrollment elementary algebra courses. Though lower than desired, and undoubtedly impacted by the challenges of COVID-19, both the high schools and college consider this a promising beginning.

In a year-end survey, instructors reported seeing a number of positive trends in their student's learning. Students enrolled in this course were engaging positively with one another and the curriculum throughout the course. They were also drawing on



and applying previous math skills, and demonstrating markedly enhanced reading and math skills. And because the curriculum is contextualized and relatable, students were making deeper connections to the math concepts and could see the value of math. As a whole, this learning experience was helping students feel more capable and confident in math than they had been in previous classes. As the program continues, instructors expect success rates to increase, as the disruption from COVID-19 lessens and as they become better familiar with the course.

Madison's math reasoning dual enrollment partnerships are breaking the mold of traditional dual enrollment. Using Quantway Core to offer math reasoning at high schools, this program is creating new paths for achieving math success and expanding who is served by dual enrollment. By investing in this type of dual enrollment as a key component of their college's student success strategy, Madison College and its high school partners are setting up more students for success by giving them a route to college and preparing them to be college-ready when they arrive. ♦

What we've learned

OVER 10 YEARS OF CARNEGIE MATH PATHWAYS implementation has shown the impact of rethinking mathematics and what is possible through a networked improvement community.

Alternative math pathways create more equitable and empowering math opportunities for students

The one-path-fits-all approach of the traditional algebra sequence has left many students struggling and isolated in their learning, and at worst, has cut students off from fulfilling their academic and career goals. By expanding access to math that is relevant to students' areas of study and career interests, we've shown how to offer more inclusive and equitable, and no less rigorous, paths to success for all students.

Statistical and quantitative reasoning pathways provide students with valuable mathematics options applicable to a variety of career paths today. They also prepare students with the tools and capacity to make sense and use of data, impacting their livelihoods, communities, and society at large. By expanding the kinds of math that students can engage in and the ways they can demonstrate mastery for college and beyond, math pathways are creating opportunities for more students to succeed in the discipline, enhance their self-sufficiency, and advocate for themselves.



Corequisite models work

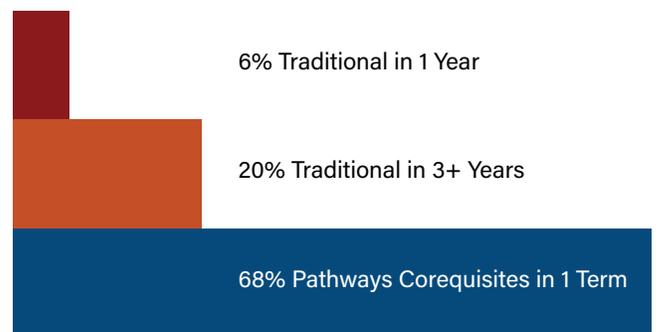
The original design of Quantway and Statway helped build the evidence base for single-term corequisite courses that engage students in both college-level and developmental coursework simultaneously. By proving that all students, even those assessed as needing remediation, can excel in college-level math right away, our programs served as a precursor to corequisite models that are serving students so effectively today.



Seeing the potential to serve even more students with corequisites, we expanded our Quantway and Statway curricula to support different corequisite models. Our curricula are flexibly designed to accommodate varying numbers of credits and different approaches to cohorting students and faculty. And we've seen, across all corequisite implementation variations of Quantway and Statway, Pathways students have achieved impressive outcomes.

By integrating developmental math knowledge with college-level content as needed, rather than requiring a sequence of remediation first, and by creating an engaging and relevant math learning experience, we can help students build key conceptual understanding and support them for success.

Carnegie Math Pathways Corequisite Success Rates



Serving Students Better and More Equitably with Corequisites at the University of Wisconsin-Milwaukee

For years, developmental math proved to be a significant barrier to graduation for many students at the University of Wisconsin-Milwaukee (UWM). UWM serves roughly 25,000 students annually, and an average of 40% of its incoming first-year students are deemed as needing additional support to succeed in college-level math. Gateway math completion rates in UWM's traditional algebra path were low—only 55%—resulting in thousands of students falling through the cracks each year. The math department knew it needed a better way to serve students.

"This really demonstrates the power of a coreq solution. We're giving all students more equitable access to college math and a better chance at success in college, career, and beyond."

In 2014, the UWM math department restructured their math offerings and introduced an active learning approach to their foundational and gateway courses. The department added a math literacy pathway using Quantway to give students not pursuing a STEM field a math option more aligned to their majors and career path, and they reduced the developmental and gateway math sequences in both their pathways to two terms. The impact on outcomes was impressive. UWM's gateway course success rates improved dramatically to 73% and 77% respectively for their math literacy and algebra pathways.

Based on the success of this initial reform, the math department took their effort a step further. Instructors sought to remove the gap where they were losing students: between the developmental course and the credit bearing gateway course. In 2017, seeing the growing evidence behind corequisite remediation, UWM decided to transition to corequisites, beginning with their Quantway course.



UWM piloted Quantway Corequisite in 2018 with tremendous success. Offering students a well-structured one-term course with thoughtfully designed corequisite supports, rich contextualized curriculum, embedded Productive Persistence supports, and a collaborative learning-based pedagogy made a difference. Between spring 2018 and fall 2021, UWM enrolled over 870 students in their Quantway Corequisite course with an average success rate of 86%.

Now, not only are more students able to enroll directly into college level math, their likelihood of success in that gateway math class is significantly higher than before. And these improvements have helped UWM reduce achievement gaps between racial and ethnic groups. Prior to the introduction of corequisites, there were considerable disparities in college level math success rates, particularly between Black and White students. Following Quantway Corequisite implementation, UWM narrowed a 32 percentage point gap to just 5 points.

UWM has radically changed their approach to supporting students in mathematics. By introducing academic and career-aligned pathways focused on active learning with structured social emotional learning supports, and redesigning them as corequisites, UWM is helping more students than ever succeed in earning their transfer-level math credit in a single term. As math faculty and Math Literacy Pathway Coordinator, Dr. Kelly Kohlmetz, notes, "This really demonstrates the power of a coreq solution. We're giving all students more equitable access to college math and a better chance at success in college, career, and beyond." ♦



Big impacts require changes across the entire system

The evidence from math pathways makes clear that we can create more equitable systems for students. Yet doing so takes institutional vision and commitment to make the structural changes—like math pathways and corequisites—that are necessary. This works best when these initiatives are connected to broader campus-wide reform. By creating a supportive environment for broad-scale change in service of students, institutions can begin to make lasting change in the place that matters most—the classroom.

MATC's Guided Pathways Approach to Improving Learning and Teaching in Introductory College Mathematics

Milwaukee Area Technical College (MATC) is the largest technical college in the state of Wisconsin, serving a diverse population of 25,000 students annually. In 2019, MATC embarked on a campus-wide Guided Pathways reform effort to create more equity-minded, student-focused systems to improve the learning experience and help more students reach their completion goals. It was through this effort that MATC's math department seized the opportunity to rethink their introductory math offerings, which were proving to be a barrier to many students. Using a Guided Pathways lens to focus on both the structure of the offerings and the way they were taught, the math department was able to make dramatic changes to better serve students.

Each term, MATC was seeing up to 1,500 students—a large majority of whom were from low income households, first generation, and/or traditionally underrepresented students in higher education—enroll in their developmental math courses. For these students, the courses extended their time to graduation and were an expense that didn't count toward their major. And with perpetually low outcomes, these courses were contributing to achievement gaps between White students and students of color at the college.

This was the case at Milwaukee Area Technical College, where educators and administrators worked together to restructure their math offerings as part of the college's Guided Pathways effort. With collective awareness of how different structures in their math program were hindering students in mathematics and their advancement toward graduation, college administrators and educators were able to design and build a better system together.



MATC's math department decided to dismantle this systemic barrier by doing away with their developmental algebra sequence entirely and instead offering more credit-bearing paths to success. They introduced a math reasoning option for college credit with no prerequisite requirements that aligned more meaningfully with many of MATC's applied programs of study.

Essential to Guided Pathways is a focus on quality instruction. Alongside the shift toward more credit-bearing math options, the department also worked to move away from lecture-style teaching to evidence-based active and collaborative instructional practices that could better engage and support students. In exploring math reasoning curricula, the math department sought a solution that would build on the pedagogical approach they'd started using in their Math for Elementary School Teachers course. This investigative and group-based instructional model was showing positive results, and their department was beginning to use the approach across all their entry-level courses.

Faculty considered a number of curricula before selecting Quantway Core. They believed the collaborative, discovery-based learning approach combined with the relevant, contextualized curriculum of the Carnegie Math Pathways design would better engage non-STEM students with math that is meaningful to their college and career goals and give them the supports needed to succeed. Additionally, they'd seen how the use of Quantway at neighboring schools like Madison College and the University of Wisconsin-Milwaukee had drastically improved outcomes.



MATC launched Quantway Core in fall 2019 and has been rapidly scaling each term to become one of the fastest institutions to scale Carnegie Math Pathways in the United States. In just two years, MATC has served over 800 students and their outcomes have increased substantially. Previously only 50% of students passed pre-algebra, the first step on their path to college level mathematics. Now 74% of students are earning college credit directly in Quantway Core.[†] For, MATC's Dean of General Education Academic & Career Pathway, Sadique Isahaku, Quantway came at just the right time. "We weren't satisfied with outcomes for our students and have been looking for tested solutions. This has opened doors to many students, who would have otherwise spent time and money in remediation, to begin college-level courses right away."

"What I see [Quantway] doing is not only powerfully impacting our students, but I feel like every member of our team is a better teacher."

The new approach is not only helping more students enroll directly in and succeed in credit-bearing math, it's also reshaping students' relationship with math. One student who struggled with and deeply resented math reported that "after taking [Quantway] I was able to not only meet expectations but exceed them as well." And the knowledge and skills gained in the course helped this same student in her subsequent math course. "I took my final math course this semester and I did exceptionally well because I was able to carry over everything [from Quantway]."

Faculty are seeing students in Quantway gain greater confidence in their mathematics abilities than in previous courses. MATC's math faculty attribute this to the curriculum itself, which they believe empowers students. The curriculum's embedded social emotional supports strengthen students' beliefs in their abilities while the relevant problem contexts connect math concepts directly to issues relatable to students' lives and decision-making.

[†] MATC's former developmental math sequence consisted of MATGEN 109 (Pre-Algebra) and MATGEN 110 (Intro to Algebra). Both were prerequisites to MAT 200 Intermediate Algebra. Students now have the choice to take either Math 107, College Mathematics or Math 134, Math Reasoning (using Quantway Core), both of which are taught in a single term for college credit. These programs are still a prerequisite to a transfer level math course, however, students not pursuing an Associate of Arts or Science can use Math 134 to meet their math requirement in a single term. Beginning fall 2022, students seeking transfer have a choice between Intermediate Algebra and the extension of the math reasoning pathway, Math 135 (Quantway College).

This change is also having a positive impact on faculty. As MATC has expanded sections and increased the number of instructors teaching the math reasoning course, they've seen more math faculty come to value group learning and recognize this approach as improving their practice. As Instructor Eric Hagedorn, who leads the math department's Quantway implementation, puts it, "What I see [Quantway] doing is not only powerfully impacting our students, but I feel like every member of our team is a better teacher. Because this curriculum requires you, if you're going to be effective, to learn how to interact with your students in a Socratic way that facilitates the learning, rather than just doing the math for them. It's not about us lecturing."

By engaging in Guided Pathways planning, MATC's math department has eliminated a system of courses that weren't working for their students. And now, with a greater focus on the students' learning experience and their success, MATC has not only introduced new pathways to student success, they're scaling a solution that is helping all of their students build a more positive and productive relationship with mathematics. In fall 2022, MATC will expand their math pathways with the introduction of Quantway College, a transfer-level course option to support those students looking to advance to a 4-year institution. According to Isahaku, the impact of this program has been powerful and worth the investment: "This is closing equity gaps and giving more students a fair chance to advance academically toward their goals." ♦



Faculty need to be supported to change the classroom experience

Nowhere can students feel an institution's commitment to them more than in the classroom. Investing in educators, who can enact change directly in the classroom, and providing space for them to be involved in the planning and rollout of institutional change is critical to building the kind of sustained support needed to implement reforms at scale.

Building a faculty learning community committed to student success

When the State University of New York (SUNY) launched its partnership with Carnegie Math Pathways to increase student math success and college completion, it knew that the place to start was investing in faculty. Faculty are one of the strongest, if not the strongest touchpoint to students on a college campus, and their experience, knowledge, and ability to enact change directly impact the classroom learning' experience and students' identities as learners. Engaging faculty in the reform process and supporting their professional development was therefore critical to ensuring student success.

In collaboration with Carnegie Math Pathways, SUNY has created a structure of professional learning supports to serve the many educators at their 2- and 4-year campuses connected through this initiative. These supports, which fall into three broad categories, recognize and engage faculty expertise and offer meaningful and motivating opportunities for educator growth and leadership.

- First, system-wide learning events are arranged annually to feature emerging research and national expertise aligned with faculty interests. These events also provide space for cross-campus learning, highlighting the insights and experiences of SUNY faculty.
- Second, SUNY faculty benefit from local supports including mentoring and coaching, discussion forums, and classroom observations facilitated or provided by their peers.
- And third, the learning community formed through these shared experiences has enabled opportunities for educators to collaborate on curricular innovations or professional development projects to benefit their practice and their students.

As a case in point, the State University of New York (SUNY), through its partnership with Carnegie Math Pathways, has exemplified a commitment to professional learning by establishing a community of mathematics educators across their institutions who are focused on sharing their learning and advancing instructional practice. This professional community has helped SUNY not only expand and sustain their math pathways initiative but to establish additional system-wide student success initiatives.



In what is typically a very isolating profession, this kind of collaboration is professionally motivating and rewarding to faculty. "For me, the [SUNY Pathways Initiative] opened a wide range of opportunities to collaborate with faculty from different institutions," Maria Alzugaray, math faculty at SUNY Suffolk County Community College said, "My professional life has become richer and definitely more engaging."

By bringing together educators to learn and share, SUNY has catalyzed a system-wide network of faculty, administrators, and advisors committed to institutionalizing math pathways and supporting ongoing professional learning and development. This investment in faculty has transformed learning and teaching at 28 SUNY institutions, benefiting more than 20,000 students and over 475 faculty, administrators, advisors, and support staff. Faculty have seen first hand how changes in their practice are impacting students, and the result is seen in increased student outcomes across the system.

"For me, the [SUNY Pathways Initiative] opened a wide range of opportunities to collaborate with faculty from different institutions. My professional life has become richer and definitely more engaging."



Going forward



THE FIRST DECADE of Carnegie Math Pathways has helped shift the paradigm of math education in the U.S. Implementing Quantway and Statway at scale has helped educators modernize the way they approach developmental mathematics and support students for success. And our network has created a new and powerful way for educators to work together to improve outcomes for students.

So far, our programs have rewritten the trajectories of tens of thousands of students, but there remain many more who could benefit. In the second decade of our work, we are committed to reaching these students by growing our

community and continuing to collaborate with educators to develop powerful, equity-centered solutions.

Every student deserves to be successful. It is incumbent upon us to build the systems and institutions worthy of our students. The Carnegie Math Pathways Network has pioneered math pathways options that make it possible for institutions to change their students' lives for the better by making math education more equitable and empowering. Looking ahead, we will continue to learn, improve, and push the boundaries of what is possible in math education—knocking down more mountains to make paths to success for all students.



Endnotes

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