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Available at **www.dcmathpathways.org/learn-about/emerging-issues-mathematics-pathways**

Chapter 15

Mathematics Pathways and Equity:

Gateway Course Outcomes

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Abstract

Mathematics pathways seek to achieve comprehensive success outcomes for all students, especially underserved populations, by combining structural approaches to move students more quickly into credit-bearing gateway mathematics courses aligned with programs of study and strategies for continuous improvement in teaching and learning. This chapter presents findings from qualitative and quantitative reports of prominent mathematics pathways approaches to provide a picture of where mathematics pathways efforts are progressing toward achieving equity goals. Significant strides have been made throughout the pathways movement to improve the overall success and mathematical achievement of developmental students while shortening the time required in remedial coursework. While mathematics pathways approaches have measurably increased success rates for Black and Latino students in particular, additional work is needed to better understand and address persistent achievement and opportunity gap issues for all underserved and underrepresented student groups. Finally, recommendations for researchers, policymakers, and practitioners are offered for consideration in the field.

Introduction

Many view mathematics pathways approaches to addressing remediation as an essential strategy for advancing student success and equity in education (Hern & Brezina, 2016). Thought leaders of mathematics pathways approaches, including Uri Treisman, executive director of the Charles A. Dana Center, and Myra Snell, co-founder of the California Acceleration Project, have emphasized equity and student success from the beginning of the mathematics pathways movement (Bryk & Treisman, 2010; Maitre, 2014; Meyer, 2013). Equity is also an important motivator for individuals engaged in improving mathematics education and student success (Ellis & Leahy, 2017; Robots & Pencils, 2017).

Indeed, equity has been a central motivator for leading educators', administrators', and policymakers' work on mathematics pathways (Charles A. Dana Center, 2016a, 2016b; Robots & Pencils, 2017). However, little has been written explicitly addressing equity and mathematics pathways. The focus of this chapter is to highlight the gateway course outcomes for students of color and low-income students in three prominent mathematics pathways initiatives: Carnegie Math Pathways, the California Acceleration Project, and the Dana Center Mathematics Pathways.

Mathematics is more important than ever before to students' future roles as scholars, as professionals, and in life due to shifts in the economy, academia, and society (Leahy & Landel, 2017; National Research Council, 2013; Treisman, 2015). However, disparities persist for underserved and underrepresented student groups, including low-income students and students of color, in mathematics success, which also impact their access to and participation in STEM-related careers and professions (Whittaker & Montgomery, 2012). Furthermore, postsecondary mathematics has been identified as one of the most significant barriers to student success and post-college outcomes (Bressoud, 2018). Given this reality, increasing numbers of stakeholders at multiple levels of the education system are addressing mathematics education as a critical component of their student success agendas.

In a growing number of states, systems, regions, and institutions, practitioners and policymakers are responding to this critical need by recommending and implementing mathematics pathways at the lower division level (Charles A. Dana Center, 2016a). These efforts are characterized by their strategies to increase program coherence and alignment, replace extended developmental sequences with accelerated and corequisite learning options, offer and assure broad acceptance of the "right" mathematics for programs of study, and improve and incorporate research-based knowledge into mathematics curriculum design and pedagogy. Mathematics pathways approaches seek to coherently combine strategies designed to address, through mathematics, the key structural, curricular, and pedagogical barriers to success in college, career, and civic roles.

Mathematics Pathways Approaches and Student Success Outcomes

What do we know about mathematics pathways and student success outcomes, relevant to equity or fairness? What evidence exists that can inform considerations of mathematics pathways through an equity lens? Multiple reports have assessed the impact of prominent mathematics pathways approaches on student success; their results are highlighted below.

Carnegie's Quantway™ and Statway™

The Statway and Quantway curricula of the Carnegie Math Pathways have been implemented

in 56 institutions in 14 states across the country. Evidence suggests that these pathways have achieved measurable success for all students, including students of color and students of poverty, in half the time relative to traditional developmental education (Carnegie Math Pathways, 2018). A 2013 report on the Carnegie Mathematics Pathways emphasized that "the pathways reach the students whom community colleges need to serve well. A disproportionate number are minority students, from families whose primary language is not English, and the first in their families to pursue a college degree" (Clyburn, 2013, p. 18).

In a comparison of Statway students to students in traditional developmental mathematics sequences at community colleges and four-year institutions across 10 states, 58 percent of Statway students earned a grade of C or above in a college-level mathematics course, while only 22 percent of the comparison group achieved the same (Huang & Yamada, 2017, p. 2).

Students of color in Statway and Quantway tended to outperform their counterparts in traditional mathematics course sequences (Huang & Yamada, 2017; Klipple, 2016). Black Statway students showed a success rate of 43 to 47 percent in the college-level mathematics courses versus their comparison group at five to seven percent. Similarly, success rates for Latinos in Statway courses ranged from 36 to 42 percent compared to Latino students in traditional courses with success rates of seven to eight percent (Klipple, 2016). Additional data showed that Statway has a positive effect across all racial/ethnic and gender groups, with Black females showing the largest gain in mathematics achievement when compared to their baseline performance (Huang & Yamada, 2017).

Results were similar for Quantway. Yamada, Bohannon and Grunow (2016) studied the success of Quantway 1 (the developmental mathematics course preparing students for Quantway 2) during the first six semesters of course implementation at 10 institutions. Researchers found that Quantway students "demonstrated significantly higher odds of success than matched comparison students in fulfilling developmental mathematics course requirements" (Yamada et al., 2016, p. 2). The study found positive effects for Quantway 1 across all gender and racial/ethnic subgroups with male Black and Latino students, demonstrating the largest increase in completion rates (Yamada et al., 2016). Success rates for Black students in developmental mathematics ranged from 46 to 48 percent for Quantway students versus 24 to 28 percent for the comparison group (Klipple, 2016). For Latinos, success rates in Quantway were 66 to 69 percent, compared to 35 percent for the traditionally enrolled Hispanic student (Klipple, 2016).

For all students, evidence indicates that Quantway and Statway also showed a positive effect on degree completion and credential attainment. In a recent study, pathway students (Quantway or Statway) earned Associates of Arts degrees and other credentials at a similar or higher rate than comparison traditional students deemed college-ready (Norman, 2017). Similarly, both Quantway and Statway students from a 2010 and 2011 cohort transferred to four-year institutions at much higher rates than the comparison students who had more time to transfer (Norman, 2017).

California Acceleration Project (CAP)

Founded in 2010, the California Acceleration Project is a mathematics pathways approach implemented in 84 community colleges in California, which multiple studies have found to measurably increase student success in less time than traditional developmental education, including for students of color and low-income students (California Acceleration Project, 2018).

For CAP, implementing redesigned pathways includes just-in-time remediation aligned to programs of study and a placement approach including multiple measures and placement floors (Hern & Brezina, 2016; Henson, Hearn, & Snell, 2017). CAP leaders have spoken out about the social justice imperative of improving developmental and mathematics education:

In the California Acceleration Project (CAP), we help faculty understand that the policies and curricula that higher education has developed to help students who are considered "underprepared" are actually making these students less likely to succeed in college—and further, that students of color are bearing the brunt of the unintended consequences (Hern & Brezina, 2016, p. 1).

Hayward and Willet (2014) analyzed student outcomes from 16 CAP colleges offering redesigned English and mathematics pathways in 2011 and 2012. All 16 institutions showed a significant reduction in time for students to complete developmental courses without any changes being made to the transfer-level course or requirements for entry into the aligned pathways (Hayward & Willet, 2014).

The researchers found that 38 percent of CAP mathematics students completed the transfer-level college mathematics course in the sequence compared to 12 percent of the comparable non-CAP students. CAP students who were placed one or two levels below completed the transfer-level college mathematics course at success rates of 53 and 41 percent, respectively, compared to comparison traditional students' completion rates of 23 and 15 percent. Ultimately, the odds of students in the accelerated mathematics pathway completing transfer-level college mathematics were about 4.5 times greater than the odds for students in the traditional sequence (Hayward & Willet, 2014, p. 29).

At Cuyamaca College in California, all students are now eligible for a college-level, transferable statistics course with co-requisite support, and 62 percent can take transfer-level math courses in business/STEM areas with or without support. All other business/STEM students have only one semester of remediation (intermediate algebra) with or without support (Henson, Huntsman, Hern, & Snell, 2017). The College of the Canyons had similar results with 100 percent eligible for transfer-level mathematics compared to 15 percent of students previously (Henson, Huntsman, Hern, & Snell, 2017).

Evidence indicates that CAP has a positive effect on success and completion among students of color. Black CAP students have the same odds of completing the mathematics pathways as their White counterparts, minimizing or successfully eliminating the achievement gap (Hayward & Willet, 2014). Likewise, at Cuyamaca College and the College of the Canyons, "gaps in access to college-level [transfer-level] mathematics were reduced or eliminated across all racial/ethnic groups. African American students' access increased eightfold, and Hispanic students' access increased fourfold" (Henson et al., p. 2). Black students in the statistics pathway in CAP at the College of the Canyons were three times as likely as their peers in the traditional developmental sequence to complete their credit-level [transferable] mathematics course within two years (Hern & Brezina, 2016).

Despite results demonstrating higher success rates for students of color in CAP completing the transfer-level course than traditionally enrolled counterparts, persistent gaps remained between White students and Hispanic and Black students. A 2015 study of CAP conducted by Hayward and Willet (2015) showed success rates for students completing a transfer-level mathematics course were approximately 44 percent for White CAP students compared to about 41 and 35 percent for students who are Black and Latino, respectively. It should also

be noted that, of students placing three or four levels below the transfer-level course (lowest two levels), 32.3 percent of Hispanics completed the transfer-level course and 48.6 percent of Black students. This was higher than White students at 42.9 percent (Hayward & Willet, 2015). While researchers note that evidence at this point may be inconclusive since results differed based on level of placement, results were still promising and suggested that the CAP pathway is well on the way to addressing—although not always eliminating—mathematics achievement gaps (Hayward & Willet, 2014).

Dana Center Mathematics Pathways (DCMP)

The Dana Center Mathematics Pathways (DCMP) model has been implemented in educational systems in over 16 states across the country. The Dana Center makes the case that many more students will successfully learn mathematics in rigorous and relevant courses that are part of well-designed mathematics pathways aligned to programs of study and that allow students to enter into college-level courses within their first year of college enrollment (Charles A. Dana Center, 2016a). This model emphasizes major structural changes that can be implemented quickly and that have a large positive impact on student success. Then, faculty and student support services can focus their attention on continuous improvement efforts through the integration and alignment of student success strategies and evidence-based curriculum and pedagogy. Equity is an integral part of the DCMP (n.d.):

> All students deserve to be served by a system that innovates in both meaningful and sustainable ways. The Dana Center Mathematics Pathways enacts the Charles A. Dana Center's mantra "Equity. Access. Excellence." through the multiple mathematics pathways approach. This approach prepares all students to use mathematical and quantitative reasoning skills in their careers and personal lives, enables timely progress toward completion of a certificate or degree, and develops empowered mathematical learners.

The evidence described below indicates that the Dana Center curriculum has measurably increased student success in Texas institutions, including for students of color and low-income students, in less time than traditional developmental education. In addition, students enrolled in the New Mathways Project statistics pathway were more engaged and achieved higher grades and pass rates when compared to those enrolled in traditional algebra-intensive mathematics courses (Charles A. Dana Center, 2016a, p. 4).

DCMP students reported being "surprised by how relevant mathematics could be to their lives and how they could more critically evaluate everyday quantitative information. . . . Many had started in the NMP classes feeling they could never grasp mathematics, and many left . . . more confident in their ability to approach the quantitative issues that they face in their everyday lives" (Rutschow & Diamond, 2015, p. 53). In addition, DCMP students completed their credit-bearing mathematics classes within one year whereas the comparison traditional student can take as long as three years (Charles A. Dana Center, 2016a).

Schudde and Kiesler (2017) found that DCMP students were more likely to complete their developmental mathematics requirements and enroll in and pass credit-level mathematics courses than students enrolled in the traditional mathematics sequence. When comparing NMP students to those in a two- or three- course traditional developmental math sequence, NMP students were about 10 percentage points more likely than their peers to pass their developmental math course, and seven percentage points more

likely to persist into the next semester. Students in the NMP *Foundations for Mathematical Reasoning* course were approximately 28 percentage points more likely to enroll in college-level math in the subsequent semester and 42 percentage points more likely to pass the class. When compared to a traditional, one-term "dev-ed" math course, assignment to the NMP *Foundations* course increased the probability of enrolling in a college-level math course the next semester by about nine percentage points and of passing that course by 25 percentage points (Schudde & Kiesler, 2017).

Co-requisite Models: A Promising Pathways Structure

In addition to the pathways approaches previously discussed, several states have shown promise in improving mathematics success and completion rates with mathematics reform and pathway implementation unique to their state (Denley, 2016; Logue, Watanabe-Rose, & Douglas, 2016). For example, beginning in Fall 2015, Tennessee scaled a co-requisite pathway model across all public universities and community colleges. Full implementation of the co-requisite model across the state showed substantial increases in completion of the credit-level mathematics course with 55 percent successful completion (compared to only 12.3 percent success for the previous traditional model) for students across all ability levels, as determined by ACT scores (Denley, 2016). When the model was revised to include a co-requisite lab instead of a co-requisite course, 75 percent of students in the co-requisite track passed the credit mathematics course, with 67 percent passing in their first semester (Denley, 2016).

Significant gains were shown across all ACT score levels. The achievement gap was essentially eliminated with successful college-level course completion for 73 percent of minority students compared to 75 percent success for all students, with 72 percent of low-income students passing the credit course. The success rate of "minority" students increased by seven times to 47.3 percent (Denley, 2016).

The City University of New York (CUNY) system has also shown gains in a co-requisite model approach with higher success rates for students enrolled in an Elementary Algebra course with a co-requisite support model (about 45 percent) compared to students enrolled only in the Elementary Algebra course at around 39 percent (Logue et al., 2016). Similarly, there were minimal differences in course success rates of approximately 67 percent for students enrolled in an Introductory Statistics course with co-requisite workshops compared to 69 percent for students in the control group. Although the percentage of course success was slightly lower for the co-requisite group, results were still impressive in that the students in the co-requisite group were those identified as needing remediation, and those in the control group who were deemed college-ready.

In addition, the statistics students with additional support passed statistics (a college-level/transferable course) at a much higher rate than the elementary algebra students, even though all students required remediation (Logue et al., 2016). The progress made by the CUNY implementation was encouraging, considering that 66 percent and 68 percent of all students in the system were Pell-eligible or Black/Hispanic, respectively (Logue et al., 2016).

Discussion on Equity and Mathematics Pathways Design

Many early implementations of mathematics pathways focused initially on developmental students because of the gains that can be made in student success through the acceleration of a pathway. Low-income students, students of color, and first-generation students are overrepresented in developmental courses, and gains in

student success in these courses help close the achievement gap. The evidence of high failure rates in traditional developmental mathematics sequences created a moral imperative to focus first on this population. Given that students requiring remediation and those less likely to complete credit-level mathematics are often students of color and low-income students, these results suggest that mathematics pathways approaches are promising strategies for increasing success for these student groups (Attewell, Lavin, Domina, & Levey, 2006; Bailey, Jeong, & Cho, 2010; Chen, 2016).

Since first developing their mathematics pathways approach, the Dana Center has expanded the vision of mathematics pathways to encompass entry-level college students because all students need and deserve the opportunity to learn mathematics content that is meaningful to their academic and career goals and learn that content in an environment designed to enhance their development as independent learners and critical thinkers. Furthermore, to imply that pathways only apply to developmental students actually perpetuates inequity by establishing a two-tiered system in which students who place directly into college-level mathematics are funneled into College Algebra or STEM pathways, and developmental students are funneled into alternative pathways. This inevitably leads to a perception that the non-algebraic-intensive pathways are less rigorous and less desirable.

The whole concept of mathematics pathways hinges on establishing a set of rigorous gateway mathematics courses appropriately aligned to programs of study that all carry equal legitimacy. Mathematics pathways advocates emphasize that students should select a pathway based on its content and alignment with their program of study, not on their placement (Charles A. Dana Center, 2014).

The Dana Center is also pushing the field to redesign and re-envision all pathways, including the traditional Algebra pathway (e.g., Intermediate Algebra, College Algebra, Trigonometry, Precalculus) leading to Calculus. There is growing evidence that the traditional pathway to calculus is not effective for students who enter at the level of College Algebra or below (Sonnert & Sadler, 2014). The Mathematical Association of America National Study of College Calculus found that three-quarters of college students who eventually study Calculus took this course in high school (Bressoud, Mesa, & Rasmussen, 2015). The study also notes that most students enrolled in college Calculus had a successful record from high school mathematics, with an average high-school mathematics grade above a B+ across all types of institutions. It is reasonable to conclude then that college calculus courses are designed for those that have previously taken this course and that have previously succeeded in mathematics—putting non-calculus students and less successful mathematics students at a disadvantage.

This demonstrates the need to reevaluate the traditional Algebra pathway to both seek ways to create access for students with less successful high school records, and to redesign mathematics programs in grades 11 and 12 to identify struggling students before they graduate and to accelerate their path toward college readiness. Marilyn Carlson's work on preparing students for calculus is exemplary of the kind of research that has broadened educators' awareness of the need to revise the traditional pathway to calculus in alignment with findings on how students learn and retain mathematical knowledge, specifically in calculus (Carlson, Oehrtman, & Engelke, 2010). This is especially critical if the United States is to expand the number of underrepresented minorities and low-income students entering the STEM fields.

Recommendations

Although significant strides have been made throughout the pathways movement to improve the overall success and mathematical achievement of developmental students while shortening the time required in remedial coursework, additional work is needed to address persistent achievement and opportunity gap issues, as well as strengthen the commitment to advancing structural reforms that do not result in unintended consequences such as tracking.

Furthermore, there is broad consensus that equity and equality are substantively different concepts and that this difference involves fairness, as opposed to sameness, and the acknowledgement of disparities when considering strategies for supporting all students' success and, for some, pursuing social justice (Gutiérrez, 2012). However, there are various perspectives and priorities related to the populations served, as well as a range of goals and strategies for advancing student success and equity (Lubienski & Gutiérrez, 2008).

The authors recommend the following research and actions that would facilitate further gains in closing achievement gaps:

- Researchers should conduct additional research to understand the conditions that led to the closing or narrowing of disparities/achievement gaps through various mathematics pathways approaches.
- There is a need for additional research into the short-term and long- term outcomes for other student groups referenced in equity and student success narratives that reflect various equity perspectives and priorities. These include women in STEM, English learners, first-generation students, adult learners, and all underserved and historically marginalized student groups and academic institutions.
- Given the variety of perspectives on equity amongst stakeholders critical to implementing change in mathematics education, researchers should identify valid and reliable indicators and performance measures aligned with multiple dimensions of equity, including access, attainment, advancement, engagement, and empowerment.
- When evaluating the progress of mathematics pathways approaches, all stakeholders should utilize metrics aligned with multiple dimensions of equity. For their part, it is incumbent upon policymakers to analyze and investigate the potential tradeoffs and unintended consequences of narrowly attending to particular dimensions of equity, disconnected from a comprehensive strategy for equity and student success.
- Practitioners, including educators and administrators, should strive to engage in open conversations to identify and address the many questions about equity and mathematics pathways that reflect various priorities and perspectives on equity and student success.

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