Advocacy Corner—High School Math Pathways: Ohio's Road to Equity in Mathematics*

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Abstract: *The authors summarize changes underway in Ohio's high school mathematics curriculum that provide alternatives to high school Algebra II and beyond. The authors share historical background of the current secondary level mathematics curriculum, the rationale for alternative pathways for Ohio's mathematics students, and the plan for implementing these pathways in Ohio schools.*

Keywords: *Alternative curriculum, pathways, Ohio Department of Education*

Introduction

For many years, the High School mathematics curriculum in Ohio has focused on preparing students to take calculus. Recognizing that this path is irrelevant for far too many students, the Ohio Department of Education has taken steps to provide high school students with alternative mathematics pathways.

In this article, we discuss how the calculus pathway became the primary focus of the mathematics curriculum in the United States. We examine the emergence of various related initiatives, including "Algebra 2 for All" and "College Algebra for All" policies. Moreover, we discuss the changing mathematics landscape in grades 9-14 that has finally provided room for the secondary mathematics curriculum to change. Lastly, we describe Ohio's plan for implementing high school math pathways as well as results from a pilot implementation of the high school math pathways in actual Ohio classrooms.

Background

The Rationale and Pacing of the Current Calculus Pathway

Mathematics is a broad area of study that includes statistics, discrete math, combinatorics, and others. How, then, did we develop a mathematics curriculum focused on the study of calculus?

*The authors would like to acknowledge the role of the Ohio Mathematics and Science Coalition (OMSC) in informing their work. See their position statement on Pathways at the following link: http://www.ohiomsc.net/reports--position-papers.html

The Committee of Ten (1892)

In 1892, the National Education Association (NEA) created and convened the Committee of Ten, a group of 10 university presidents and school headmasters. Responding to the growth of new industries and the growing popularity of college following the Civil War, the group re-imagined the mathematics curriculum for a new era, with an emphasis on arithmetic in the early grades and algebra, plane geometry, solid geometry, and financial applications at the secondary level (NCTM, 1970). This curriculum remained in place for about seventy years.

The Launch of Sputnik (1957)

Then, in October of 1957, in the midst of the Cold War, the Russians surprised the U.S. government by launching their rocket, Sputnik, and beating the U.S. in the race to space. The U.S. government responded by devoting resources to mathematics and science education (Klein, 2002).

Many U.S. school districts adopted new mathematics and science textbooks that placed all high school students in courses that were traditionally considered college preparatory programs. Among the most popular was *Structure and Method*, published by Houghton Mifflin at the beginning of the 1960's and co-authored by Mary P. Dolciani. The textbook series was influential, creating a common high school mathematics curriculum that remained consistent until the 1980's (Klein, 2002).

The *Structure and Method* approach was rooted in functions and equations topics essential for the preparation of engineers (and thus ultimately the study of calculus). Dolciani and her team essentially constructed the definition of "school mathematics" which has been in place for the last seventy years.

The Race to Calculus

In the mid-1990's, influenced by the knowledge that many Japanese schools teach Algebra 1 in eighth grade, the U.S. Department of Education began advocating for more eighth grade students to take Algebra 1 (DOE, 2018). According to the U.S. Department of Education, by 2018, 24% of 8th grade students were taking Algebra 1 in eighth grade. (DOE, 2018). This caused schools to track students, accelerating some while holding others back. As a result, a "Race to Calculus" was created with students (and their parents) eager to show that they could complete the "race" as quickly as possible.

Consequences to the Race to Calculus

Too much, too fast

As the volume of content teachers were asked to cover in secondary-level mathematics courses increased, the focus of instruction shifted to a focus on procedures—since teaching for deep, conceptual understanding often requires more time than teaching for computational mastery. Younger and younger students began taking algebra—despite the fact that many weren't developmentally ready for the abstract thinking required in a formal algebra course. Linda Gojak, former president of NCTM, wrote the following in a 2013 President's Message.

> Many students and parents interpret taking algebra in the seventh or eighth grade as an indication of a level of superior intelligence—a status symbol. My experience, both as a student and as a teacher, leads me to believe that we do more harm than good by placing students in a formal algebra course before they are ready, and few students are truly ready to understand the important concepts of algebra before eighth grade. Many students should wait until ninth grade.

Despite such recommendations, the percentage of high school students taking Calculus has rose from 5% to 15% since the mid 1980s (Sparks, 2015; Broussard, 2015).

Disparities between secondary- and university-level calculus

In 2015, The Mathematical Association of America (MAA) completed a five-year study of introductory calculus offerings at 213 colleges. The MAA concluded that taking calculus in high school did not necessarily translate to success in university-level calculus. Researchers reported that students in college calculus classes tended to lose confidence as the semester progressed.

Taking calculus in high school did not seem to have an effect, positive or negative, on college calculus performance unless students achieved a score of 3 or better on the Calculus Advanced Placement Exam. "This finding draws into question much of the rush to calculus in high school. An alternative to calculus in high school that focuses on strengthening students' understanding of algebra, geometry, trigonometry, and functional relations while building problem solving skills would be very welcome" (Bressoud, Mesa, & Rasmussen, 2015).

Algebra 2 for All

In the early 2010's, Achieve and other educational groups led a charge to convince states to adopt "Algebra 2 For All" policies under the guise of increasing workforce readiness skills. Advocates of the policy noted that completion of Algebra 2 was a leading predictor of workplace success (Carnevale & Desrochers, 2003).

Unfortunately, implementation of the "Algebra 2 For All" policy did not produce outcomes that Achieve and others had anticipated. Mandating "Algebra 2 For All" did not lead to college readiness for all students. Instead the requirement became an irrelevant barrier to graduation for many.

To address this problem, many schools began to offer multiple flavors of Algebra 2 within the same high school: for instance, an Honors Algebra 2 focused on preparing students for Calculus; an Algebra 2 course for the majority of students to satisfy graduation requirements; and an Algebra 2-Part A course for struggling students, basically a review of Algebra 1 with a sprinkling of Algebra 2. The wide range of offerings rendered "Algebra 2" meaningless on a student's high school transcript; however, it did create a need in Ohio for relevant Algebra 2 alternatives.

Changing Landscape

National Recommendations Surrounding High School Math Pathways

In *Catalyzing Change in High School Mathematics* (2018), the National Council of Teachers of Mathematics (NCTM) advocates the following purposes of school mathematics: (1) expand professional opportunity; (2) understand and critique the world; and (3) experience wonder, joy, and beauty (NCTM, 2018). In the same document, NCTM calls for all high schools to offer options beyond the essential concepts such as Algebra 1 and Geometry. Students need experiences with quantitative literacy, advanced quantitative reasoning, financial mathematics, history of mathematics, mathematical modeling, and discrete mathematics (p. 88). Specifically, *Catalyzing Change* recommends high schools to offer mathematics pathways.

> High schools should offer continuous four-year mathematics pathways with all students studying mathematics each year, including two to three years of mathematics in a common shared pathway focusing on the Essential Concepts, to endure the highest-quality mathematics education for all students (NCTM, 2018, p. 7).

Regarding the remaining courses, NCTM states that "the direction of this later high school mathematics study should be based on the student's own needs, goals, interests, and aspirations. Furthermore, this continued study of mathematics beyond the Essential Concepts must be based on each student's desire to pursue the future that the student imagines for himself or herself rather than on any difference in mathematical ability perceived by anyone else." (NCTM, 2018, p. 85).

The position of NCTM is echoed by the University of Texas at Austin Charles A. Dana Center on their Mathematics Pathways page (http://dcmathpathways.org/) and JustEquations.org, an organization that serves to advance "evidence-based strategies to endure math policies that give all students the quantitative foundation they need to succeed in college and beyond" (Just Equations, 2021). In their report, "Branching Out: Designing High School Math Pathways for Equity," Just Equations connects curriculum reform to student equity.

> We need to eliminate barriers to opportunity based on income, race, ethnicity, gender, and any other factors beyond the control of the student, to move from a deficit model to an asset-based narrative. We want each student's experience with mathematics in school to lead to worthwhile opportunities that reflect the student's aspirations and include flexibility to change direction (Daro & Asturias, 2019).

Math Pathways at Higher Education

Changes in the high school curriculum do not exist in isolation. Colleges are beginning to see that the single pathway to taking calculus is not necessarily beneficial for addressing needs in industry (Dana Center, 2019). Changes to the mathematics landscape at either level open the door for changes to math curriculum at other levels.

Problems with College Algebra

Traditionally, College Algebra (i.e., Algebra 2's higher education equivalent, or "cousin") became a minimal core requirement for all college students. Although the original purpose of College Algebra was to prepare students to succeed in calculus, the purpose of the course has become diluted over time (Ohio Math Initiative, 2014). The reality is that only a small number of college students who take College Algebra continue onto calculus, and the content of the course was arbitrary and irrelevant for most majors (Ohio Math Initiative, 2014). Aside from engineering, science, math, and some business majors, few other majors require calculus.

New Courses Developed by the Ohio Mathematics Initiative

To help improve student success and college completion rates, the Ohio Mathematics Initiative (OMI) has removed College Algebra as the default mathematics course for non-STEM majors. As an alternative, OMI has created entry-level mathematics courses that align more closely to the content that students will encounter after graduation—for instance, Quantitative Reasoning and Introductory Statistics (Ohio Mathematics Initiative, 2014; Foley & Wachira, 2021). Mathematics pathways in Ohio are broadening even further to include more entry-level courses such as Data Science, Discrete Mathematics, and Technical Math. As "College Algebra for All" has disappeared, the time has come to reevaluate the "Algebra 2 for All" mandate at the high school level to create greater coherence between secondary and postsecondary mathematics.

Ohio Strategic Plan: Each Child, Our Future

In 2019, Ohio launched its strategic plan for education titled "Each Child, Our Future." The vision of the plan is to provide each child in Ohio with opportunities to be challenged to discover and learn—to be prepared to pursue a fulfilling post-high school path and empowered to become a

resilient lifelong learner who contributes to society. Strategy 10 of the plan focuses on high school success and postsecondary connections while stressing the need for students to have multiple pathways to ensure student success (Ohio Department of Education, 2019). This strategy allows for transformation to occur at the state's high schools.

The Solution: Strengthening Ohio's High School Mathematics Pathways Initiative

The Process

In 2019, The Ohio Department of Education, partnering with the Ohio Department of Higher Education, began the Strengthening Ohio's High School Math Pathways Initiative with the purpose of aligning secondary and postsecondary math pathways. Current Ohio law requires that all students take four units of mathematics including Algebra II or its equivalent. Like its higher education counterpart, College Algebra, Algebra 2 was not meeting the needs of all students.

Ohio convened several stakeholder groups and charged them with the following tasks: (1) create new math pathways stemming from Algebra 2 equivalent courses; (2) provide guidance around implementation; (3) align systems and structures; and (4) be guardians of equity. An advisory council, which included organizations such as the Ohio Mathematics Initiative, the Ohio Council of Teachers of Mathematics, the Ohio Association of Community Colleges, the Buckeye Association of School Administrators, the Ohio School Boards Association, the Ohio Parent Teacher Association, the Ohio School Counselor Association and others aligned the systems and structures between high school and college. Additionally, Ohio created the Math Pathways Architects group made up of secondary and postsecondary mathematics faculty to align curricula across the two levels. As each new pathway was created, a content-specific workgroup was formed as well to provide more content-specific expertise for teachers.

There are four overarching goals in creating the new pathways:

1. To promote equity, any courses that are created should be equally rigorous to the traditional math pathway.
2. Pathways should be relevant to a student's future career goals. Not only will relevant courses help students achieve their goals, but they will also create more buy-in from the students and help develop a positive math identity.
3. Pathways should also be flexible in case students change their minds about future plans.
4. Pathways should be coherent with pathways in higher education to provide students with a seamless transition

The Outcome

The committees decided that equivalence would be based on the level of thinking, reasoning, and rigor rather than equivalent content. They defined rigor in the following terms.

> Students use mathematical language to communicate effectively and to describe their work with clarity and precision. Students demonstrate how, when, and why their procedure works and why it is appropriate. Students can answer the question, "How do we know?"

The Math Pathways architects, aligning their work with the recommendations of NCTM and others, recommended that students should still study algebra and geometry and then have the option

of taking an Algebra 2 or an equivalent course. Ohio has proposed *four* Algebra 2 equivalent courses that align with postsecondary math pathways: (1) Quantitative Reasoning, (2) Data Science Foundations, (3) Statistics and Probability, and/or (4) Discrete Math/Computer Science.

Districts may choose to offer one or more of these options. Figure 1 shows the five potential choices for an Algebra 2-equivalent course and potential options for an additional senior year course aligned to students' future career aspirations.

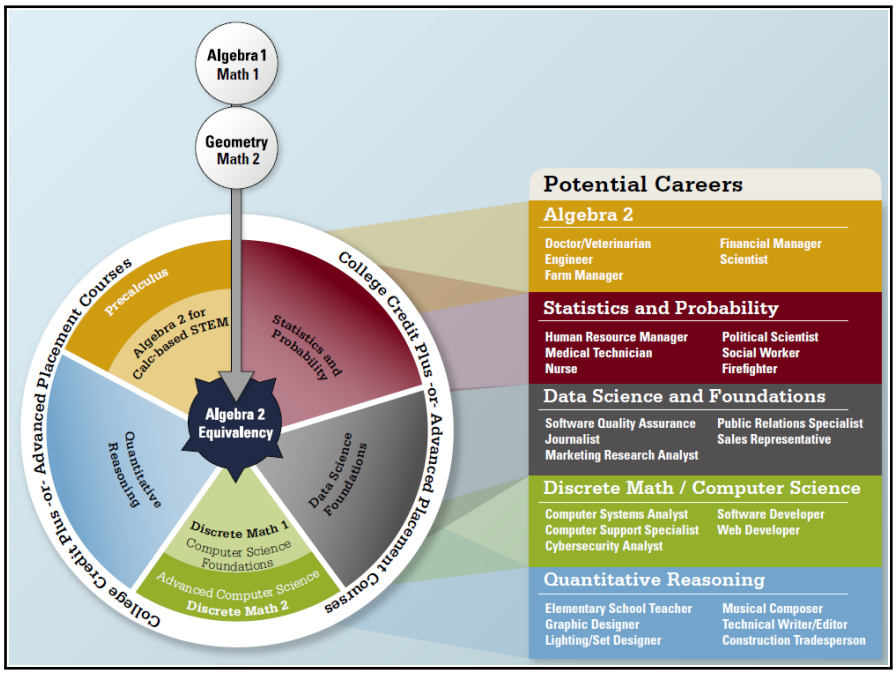

Figure 1: *Draft of potential course options beyond Algebra 1 and Geometry.*

Students who are pursuing a postsecondary degree requiring Calculus should still stay on the Algebra 2 to Calculus Pathway as shown in Figure 2. Other students are advised to choose an Algebra 2-equivalent course based on their career aspirations and district offerings.

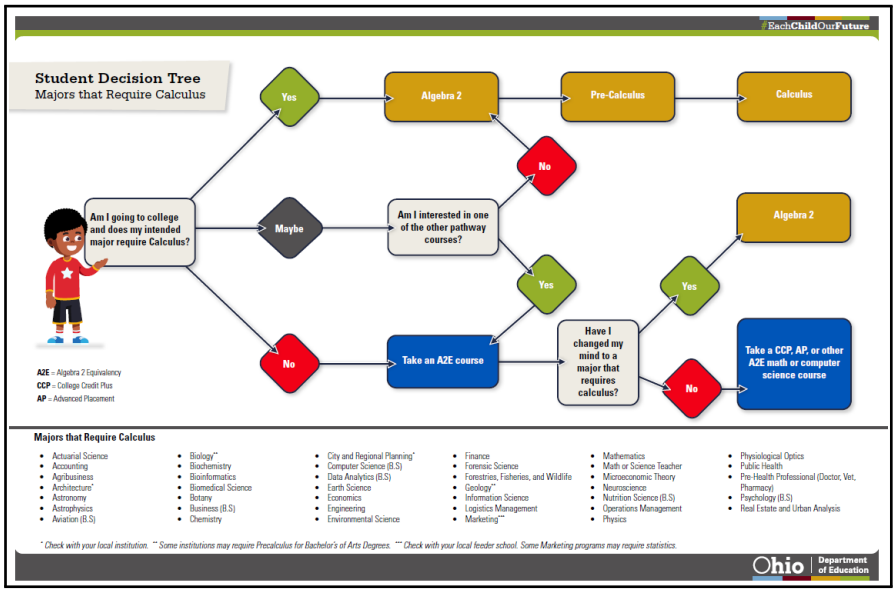

Figure 2: *Draft of student decision tree.*

Course Resources, Development, and Pilots

A workgroup, comprised of secondary and postsecondary math faculty, was formed for each pathway to develop guides to assist teachers with relevant standards and to develop or recommend curricular resources. Three of the proposed pathways (Quantitative Reasoning, Discrete Math/Computer Science, and Data Science Foundations) will have course pilots to support a lack of curriculum and teacher content knowledge in these areas. The workgroup was also charged with providing advice regarding the piloted courses.

As of this writing, Ohio has developed curriculum for two courses—namely, Quantitative Reasoning and Discrete Math/Computer Science. Below, we describe each of these courses in greater detail.

Quantitative Reasoning

In 2018, secondary and post-secondary faculty in Ohio created a high school transition course, titled Mathematical Modeling and Reasoning (MMR), with the purpose of helping students earn a remediation-free score in mathematics. MMR is a year-long quantitative reasoning course focusing on student-centered pedagogy. As an inquiry-based course, students are presented with real-world problems that they solve collaboratively in small groups. Standards of Mathematical Practice (CCSSI, 2010), communication, and collaboration are in the forefront of the course (Miller & Walls, 2021).

The MMR pilot began during the 2019-2020 school year in twenty-two schools across various regions and typologies of the state. In order to teach the course with fidelity, participating Ohio high school teachers were required to participate in a multi-day summer workshop and ongoing professional development throughout the school year. To maintain rigor and a smooth transition between institutions, each initial pilot teacher was assigned a higher education math faculty member as a collaborator. Despite the COVID-19 pandemic, the pilot expanded to about 50 schools in 2020–2021 and to about 80 schools in 2021–2022.

To align with the Strengthening Ohio's High School Math Pathways Initiative, the MMR course will be modified for the 2021-2022 school year to be an Algebra 2 equivalent course, with greater attention given to more advanced topics such as trigonometry. (For more information, see http://education.ohio.gov/Topics/Learning-in-Ohio/Mathematics/Resources-for-Mathematics/Mathematics-Modeling-and-Reasoning-Course-Pilot)

Anecdotally, teachers report that their MMR students appreciate the way that the course presents mathematics through relevant, real-world contexts. Also, many MMR teachers report that the intentional inquiry-based teaching of this course has impacted their teaching in other courses, encouraging students in other classes to take a more active role in their learning. Unfortunately, data collection during the 2020–21 academic year was suspended due to COVID-19, but the data collection process has since resumed in 2021–2022.

Data Science and Foundations

The Data Science and Foundations Workgroup selected UCLA's *Introduction to Data Science* (www.introdatascience.org) curriculum to pilot statewide. This curriculum incorporates R (a statistical programming language) and R Studio (an open-source software that uses R) with high school Statistics and Probability standards. The UCLA curriculum aligns nicely with the emerging Data Science gateway course at Ohio's higher education institutions since both promote the use of R/R studio. The course is being piloted by 17 high schools across the state. (See http://education.ohio.gov/Topics/Learning-in-Ohio/Mathematics/Resources-for-Mathematics/Math-Pathways/Data-

Science-Foundations for more information). The standards-based document for this course will include both mathematics and computer science standards.

Discrete Math/Computer Science

By Ohio law, students can satisfy the credit of Algebra 2 by taking an Advanced Computer Science course using the Advanced Computer Science Standards; however, these standards can be taught without using any advanced mathematics. Without advanced mathematics, many students wishing to pursue a career in computer science are hindered from careers requiring a degree. They are also at a disadvantage in the field as most computer science careers require advanced algorithmic reasoning. Currently, students who choose this option have to sign a waiver acknowledging that the lack of advanced mathematics may prohibit them from pursuing postsecondary education.

Additionally, combining Discrete Mathematics and Computer Science concepts allows more students to access computer science concepts as mathematics teachers can teach the course. This, in turn, opens the doors for more students to pursue computer science at the postsecondary level creating greater equity in the field.

A Discrete Math/Computer Science Workgroup is currently creating the course curriculum. The teacher guides and course curriculum for this course will include both math and computer science standards. The course curriculum and the teacher guides are still under development and will not be published until at least 2022–2023. If all goes as planned, the course will be initially piloted in the 2022–2023 school year.

Statistics and Probability

The Statistics and Probability Workgroup is developing guidance documents to help high schools plan their Statistics and Probability courses and for selecting appropriate resources. The teacher guides for this course will focus on aligning mathematics standards to the Advanced Placement Statistics and Ohio's dual-credit Introductory Statistics course. The Department of Education may also leverage the work of the Ohio Materials Matter Initiative (http://education.ohio.gov/Topics/Learning-in-Ohio/OLS-Graphic-Sections/Resources/High-Quality-Instructional-Material) which focuses on helping districts select high-quality instructional materials to support this pathway.

Algebra 2

Now that Algebra 2 does not have to serve as a graduation requirement, it can do what it was truly designed to do: prepare students for the Calculus-based STEM pathway. The Algebra 2 Workgroup redesigned the teacher guides with a greater focus on preparing students for Ohio's dual-credit Precalculus course. The Department of Education may also leverage the work of the Ohio Materials Matter Initiative to support this pathway.

Launching the High School Math Pathways

The Ohio Department of Education has worked in tandem with the Ohio Department of Higher Education and the Ohio Math Initiative to align secondary and postsecondary mathematics, systems, and structures, and also to communicate these changes. They convened virtual meetings of four-year universities with representatives from offices of the provost, admissions, advisors, and math department chairs/leads. The goal of bringing university members together was to create coherence at 4-year institutions and to help ensure that students wouldn't be negatively impacted by taking an Algebra 2 equivalent course.

The Ohio Department of Education published the teacher guides for the Algebra 2 equivalent courses (excluding Discrete Math/Computer Science) on their website in Fall 2021. At the time of this writing, they are also creating toolkits for administrators, teachers, counselors, and parents to help implement the new pathways. Additionally, they hosted a number of virtual Math Pathways symposia during Fall 2021 to bring together various stakeholders and to launch the initiative statewide.

Benefits of New High School Math Pathways

For more than a half century, our students have engaged in a mathematics curriculum focused on preparing them for calculus. Such an approach has been costly for marginalized students. Fortunately, the new high school math pathways will help to eliminate calculus-based barriers. Having all Ohio high school students master Essential Concepts in the first two years of high school enables students to explore mathematical pathways during their Junior or Senior years. This will benefit students and teachers, alike, as students become more confident in their abilities, as mathematics instruction becomes more equitable, and as students from underrepresented groups engage in areas of mathematics rooted in real-world problem solving, data, and technology.

Improving Mathematical Identity and Agency

The "Race to Calculus" has turned many students away from mathematics since its pace promotes memorization over deep conceptual understanding (Boaler, 2016). The rapid pace also impacts students' mathematical confidence as speed is emphasized over understanding. Students who can't maintain the pace feel discouraged and resentful, developing a dislike for mathematics and negative mathematical identities. For too many, the mantra "when will we ever use this" is a popular refrain. In contrast, "A high sense of agency allows and encourages students to continue with a rigorous course of study in mathematics" (NCTM, 2018). Relevant pathways that connect to students' career interests have been shown to strengthen student confidence in mathematics.

Improving Equity and Representation in Mathematics

A single calculus pathway has exacerbated inequities among marginalized groups while cutting students off from lucrative careers that require mathematical know-how (Dana Center, 2018). Mathematics opens students to a variety of career options. For example, statistics and computer science both require numerical logic and sequencing and are the basis of many lucrative careers.

The first 15 jobs listed in *U.S. News and World Report's* 2021's 100 Best Jobs (https://money.usnews.com/careers/best-jobs/rankings/the-100-best-jobs) are in health fields or computer/information technology fields—all of which require substantial college-level mathematics including calculus, statistics, and/or computer science. Generally speaking, the more mathematics that is required in a career field, the higher the salary. Equity has been a driving force in the Strengthening Ohio's High School Mathematics Initiative.

To discourage tracking based on ability, Ohio is messaging that all its Algebra 2 equivalent courses are equally rigorous and college-preparatory. To help ensure that rigor is maintained, Ohio has developed a common definition of rigor that cuts across courses.Additionally, each of the new Algebra 2 equivalent teacher guides share a common critical area of focus: Communication and Analysis.

Some school district personnel, teachers, and guidance counselors may reinforce the perception that there is no purpose to persevering in the study of mathematics when students have no interest in pursuing a STEM-based career (Daro & Asturias, 2019). Therefore, it is essential that students choose their math pathway based on future aspirations rather than perceptions. To ensure this,

Ohio has included school counselors in planning from the start. Counselors across the state have created resources for schools to implement the pathways equitably. They are also helping to guide the Ohio Department of Education in creating training specific to the new mathematics pathways.

Exposure to Other Areas of Mathematics

Another cost is that students are not exposed to emerging fields of mathematics such as data science or statistics. U.S. job needs are changing (Sparks, 2015). For instance, in the current job market there is a greater need for employees with expertise in data science. "As of 2017, the U.S. Bureau of Labor Statistics estimations showed that jobs that require data literacy and statistics are among the 10 fastest-growing occupations in the country" (Sparks, 2015). "New course pathways such as statistics and data science may better prepare most students (even those pursuing STEM) for 21st century careers and citizenship" (Burdman, 2019). However, the proportion of time typical U.S. K–12 mathematics students study data and statistics, particularly at the high school level, is relatively low (Chmura, 2018). Ohio's Algebra 2 equivalent courses will expose students to other in-demand fields of mathematics at an earlier age to help create awareness of different career options and recruit underrepresented populations into those lucrative careers.

Potential Challenges and Solutions

Capacity

Implementing math pathways comes with some challenges and obstacles. For one, smaller districts that have fewer math faculty members may find it challenging to offer more than one pathways course. However, recent technological upgrades precipitated by the pandemic may provide a possible solution—with technology, neighboring schools can share resources and staff. Districts can also evaluate other dead-end course offerings that they currently offer and replace them with pathways courses.

College Admissions

Student and parents may be concerned about students showing college readiness or standardized test readiness. The Mathematical Association of America (MAA) and NCTM issued a joint statement in 2012 in response to this.

> . . . the ultimate goal of the K–12 mathematics curriculum should not be to get students into and through a course in calculus by twelfth grade but to have established the mathematical foundation that will enable students to pursue whatever course of study interests them when they get to college." Time and communication will be needed to assure students and parents that the rigor and content of these alternatives will still prepare students to meet college admission requirements and acquire merit-based scholarships.

In recent years, many colleges have revisited admission criteria and its impact on student equity. For instance, during the pandemic, many colleges became test-optional. In California and Washington, public institutions no longer require the ACT or SAT for admission. The California University system also allows courses other than Algebra 2 for admittance. (See https://hs-articulation.ucop.edu/guide/a-g-subject-requirements/c-mathematics/). Ohio is making progress in this area by bringing universities to raise awareness of such issues.

Flexibility

Some have expressed concerns about students "falling behind" by selecting a math pathway in the junior year. However, with all students obtaining the same foundational Essential Concepts

in the earlier grades, this should not be an issue. Research at postsecondary institutions suggests that students enrolled in quantitative and statistical pathways have a success rate 3-4 times that of traditional pathways students (Huang, 2018). Additionally, research indicates that students who take a statistics or data science course instead of an Algebra 2 or College Algebra course are better prepared for 21st century careers (Burdman, 2019).

Conclusion

Ohio like many states across the nation are rethinking "Algebra 2 and College Algebra for All." As the college landscape has changed, high schools are able to create similar changes. Ohio has seized the moment to create new high school math pathways centered around Algebra 2 courses such as Quantitative Reasoning, Data Science Foundations, Statistics and Probability, and Discrete Mathematics/Computer Science. These math pathways in the state have the potential to increase positive mathematical identity and promote student agency; to increase equity and representation in mathematics; and to expose students, including those from underrepresented groups to other in-demand fields of mathematics rooted in data and technology.

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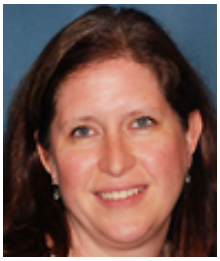

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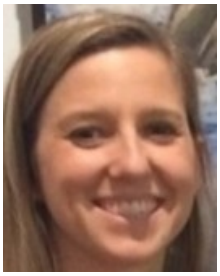

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