Mathematics Pathways

Designed for Learning Success

A REPORT ON THE 2015 OHIO STUDENT SUCCESS SUMMIT

Ohio Mathematics Initiative

Ohio Mathematics Initiative

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Preface

by Chancellor John Carey and Superintendent Richard A. Ross

"If you keep doing the same things, you'll keep getting the same results."

Most of us have encountered this kind of thinking in our personal or professional lives, particularly in situations where people seek to protect the status quo either because the results they are getting seem to be "good enough" or because they are cemented in the present.

Ohio's mathematics educators are challenging this way of thinking. They know that "good enough" is no longer acceptable in a world that prizes and rewards knowledge and that makes ever-increasing demands on its workers.

At the state and local levels, leaders in education must look for new practices in mathematics education that will help every student – from preschool through postsecondary learning – develop the quantitative skills needed to succeed in the classroom, careers and life.

In the past, Ohio's P-12 and postsecondary sectors have operated as ***separate silos***, with different financial structures, different accountability requirements and different expectations for success. This has made coordination difficult and instruction and curricular alignment challenging. As a result, it has left our students to navigate on their own the uncertain transition from one education sector to the next. Too often, they have not been successful.

The good news is that the silos are coming down. There is more collaboration between P-12 and college educators, and nowhere is this cooperation more evident than in the ***Ohio Mathematics Initiative***, which is grounded in the recognition that the mathematical sciences give students the quantitative tools, logical reasoning, and analytic and problem-solving skills that define a highly qualified and competitive workforce.

New practices and better results are needed for no other reason than this:

> *If Ohio continues doing the same things it's doing today, with its current rate of growth in postsecondary credentials,* ***by 2025 the state will have 60,000 fewer citizens with postsecondary education credentials than it has today****.*[1]

That's the projection of the highly regarded National Center for Higher Education Management Systems, which points to the state's changing demographics – its older and more racially and ethnically diverse population – and to the number of low-income and minority students, as well as first-generation and adult learners, who traditionally have been underrepresented on college campuses and among college graduates.

[1] National Center for Higher Education Management Systems (2012). http://www.nchems.org/

But there is another reason to embrace new practices and aspire to better results.

Participants in the *Ohio Mathematics Initiative* understand that the path to higher education and upward mobility ends abruptly for many students due to high failure rates in remedial and college entry-level mathematics courses that aren't relevant to their majors or other areas of interest. Now, high school and college mathematics educators are working to improve success and completion rates by:

- Clarifying academic standards and expectations at all grade levels;
- Aligning high school and postsecondary mathematics content and instruction; and
- Developing alternative mathematics pathways connected to coherent programs of study for students majoring in mathematics, other mathematics-intensive majors and majors that are not mathematics intensive.

The Ohio departments of Education and Higher Education are committed to the success of the *Ohio Mathematics Initiative,* which is opening the door to a more relevant mathematics education for all Ohio students as it provides a blueprint for other states that want to transform their mathematics education programs.

John Carey
Chancellor
Ohio Department of Higher Education

Dr. Richard A. Ross
Superintendent
Ohio Department of Education

About the Summit

On a crisp spring morning in late April, postsecondary mathematics faculty, academic advisors and institutional leaders from Ohio's public colleges and universities – joined by mathematics teachers and counselors from high schools and career centers in their service areas – converged on the Greater Columbus Convention Center for the 2015 Ohio Student Success Summit. Nearly 225 mathematics educators gathered with a shared understanding that much of 21st century science and engineering – as well as medicine, manufacturing, transportation, communication and a range of economic enterprises – depend on the quantitative sciences.

They also came out of curiosity:

- to find out how the adoption of Ohio's New Learning Standards would impact high school graduates' readiness for and success in college-level mathematics courses;
- to discover how new teaching and learning strategies could be used to support learners for whom mathematics can be an insurmountable obstacle to earning a high school diploma, or a highly valued postsecondary degree or certificate; and
- to learn more about how the state's public colleges and universities are developing or revising college-level mathematics courses to align with the skills and knowledge students need to be successful in their chosen programs of study.

Ohio is leading the nation in college-level mathematics reform

Ohio's leadership in the transformation of postsecondary mathematics education was confirmed with its selection as one of six states to participate in a two-year Building Pathways into Programs of Study initiative directed by Complete College America and the Charles A. Dana Center at The University of Texas at Austin. Funded by the Lumina Foundation, the initiative is designed to dramatically increase the percentage of students who pass gateway mathematics courses and enter programs of study in one academic year by building multiple pathways into and through college-level mathematics. The other states in the project are Colorado, Indiana, Missouri, Montana and Nevada.

In announcing Ohio's selection, Complete College America's Bruce Vandal said, "Complete College America recognizes the outstanding work in Ohio to create stronger pathways through college-level mathematics into programs of study at all of its postsecondary institutions. We applaud the work of the Ohio Department of Higher Education and the dedicated faculty and other postsecondary leaders at Ohio's institutions that are dedicating many hours to this work to ensure that more Ohio students can successfully complete the gateway math courses that are most appropriately aligned to their desired programs of study."

Vandal continued: "The work done to date in Ohio is leading the nation. Many other states aspire to the goals of the Ohio initiative, and the accomplishments achieved by Ohio leaders will provide a blueprint for other states and postsecondary institutions. "

At the outset, Summit participants heard that Ohio's schools, colleges and universities are doing a better job of educating an increasingly diverse group of students than ever before. Yet, the results of these efforts are not what they need to be. Too many young people are dropping out of high school before earning a diploma, in many cases because they don't see the connection between school and what they will be doing for the rest of their lives. Too many high school graduates are not going directly on to college, and many of those who do must take remedial courses because they are not ready for college-level work. And too many postsecondary students never complete their degree or certificate programs.

According to Dr. Stephanie Davidson, Vice Chancellor for Academic Affairs at the Ohio Department of Higher Education, steps have been taken to improve high school students' readiness for college and careers. Remediation rates are decreasing. The gaps between what high schools are teaching (and what they believe is important for success in college) and what postsecondary educators expect of students in entry-level courses are narrowing.

To confirm the state's determination to bring traditional secondary and postsecondary "silos" down, Dr. Davidson reported that the Ohio departments of Education and Higher Education have been housed in the same building where they are sharing facilities and working collaboratively to develop and advance matched learning agendas that are student-centric – aligned with the skills and knowledge students need to be successful in their chosen programs of study.

Signed by Governor John Kasich on June 30, 2015, House Bill 64 gave the Ohio Board of Regents a new name – the Ohio Department of Higher Education. The name change will become effective on September 28, 2015, but the agency's mission will remain unchanged.

To avoid confusion, the agency's new name – the Ohio Department of Higher Education – will be used throughout this report, even for actions taken before the effective date of the name change.

"Mathematics is a stumbling block for many students," Davidson said. "So from the outset, we knew it had to be addressed first. We knew we needed better linkages between what students learn in high school and what they will be expected to know in college. We knew we needed better options for students so the mathematics courses are better connected to the knowledge and skills students are going to need in their careers. And we knew we needed better ways to teach mathematics so we can reach more students, better preparing them for the road ahead."

"We must do better," Davidson continued. "We must do things differently. And that's what this Summit is all about."

The agenda for the 2015 Ohio Student Success Summit can be found on page 7 of this report.

Ohio Student Success Summit

Defining Mathematics Practices and Pathways

Friday, April 24, 2015

Greater Columbus Convention Center

Agenda

9:00 a.m.
Registration

9:30 a.m.
Welcome
Stephanie Davidson, Ohio Department of Higher Education

9:40 a.m.
Ohio Mathematics Initiative Overview and Summit Overview and Goals
Andrew Tonge, Kent State University
Serita McGunia, Cuyahoga Community College

10:00 a.m.
The Ohio Mathematics Standards and The Ohio Transfer Module: Mathematics
Bradford Findell, The Ohio State University
Ricardo Moena, University of Cincinnati, and Chair, Ohio Transfer Module, Mathematics
Brian Roget, Ohio Department of Education
Michelle Younker, Terra State Community College

10:45 a.m.
Break

11:00 a.m.
Mathematics Across the P-16 Continuum
Fred Dillon, National Council of Teachers of Mathematics

12:00 p.m.
Lunch and Shared Discussion

12:45 p.m.
Greetings
Chancellor John Carey
Superintendent Richard A. Ross

1:00 p.m.
Plenary Presentation: National Perspectives on Mathematics Practices/Pathways
Joan Ferrini-Mundy, National Science Foundation

2:00 p.m.
Break

2:15 p.m.
Concurrent Discussion/Work Sessions (and facilitators)

Use of Calculators
Douglas Dosky and Christina Therkelsen

21st Century Mathematical Skills
Larisa Russell and Jené Drage

Instructional Design: Embedding Mathematical Practices
Tony Xenos, Bradford Findell and Endora Kight

12th Grade Transitional Courses
Krista Maxson and Deidra Davis

Advanced Credit Opportunities in High School: College Credit Plus, AP, International Baccalaureate
Kristin MacDonald, Todd Eisworth and Brian Roget

Advising and Counseling in Mathematics Pathways to Support Individual Goals and Plans
Sandy Siegrist and Sarah Collins

Assessment
Andrew Tonge and Jim Wright

Facilitated Shared Mathematics Work Interactive Session
Bowen Kerins

3:15 p.m.
Plenary Presentation: Perspectives from the Day
Susan Wood, Charles A. Dana Center, The University of Texas at Austin

3:45 p.m.
Closing Remarks
Uri Treisman, Charles A. Dana Center, The University of Texas at Austin
Stephanie Davidson

Ohio Mathematics Initiative: An Overview

The Ohio Mathematics Initiative is a collaborative effort of mathematics faculty members from Ohio public colleges and universities (University System of Ohio) and Ohio high schools who came together to revisit and rethink mathematics courses, curricula and their relationships with other disciplines. One catalyst for the initiative was the establishment of Ohio's remediation-free standards, guaranteeing placement into college credit-bearing courses for all Ohio students achieving at or above a benchmark assessment score and matriculating to an Ohio public college or university. Other drivers of this work were increasing difficulties among mathematics faculty with processes and criteria for course and credit transferability within the Ohio Transfer Module (OTM), and the implementation of Ohio's New Learning Standards for K-12 students with the effect those rigorous standards will have on the preparation of incoming college students.

The Ohio Mathematics Initiative began with the Ohio Mathematics Steering Committee, a convening of 12 mathematics faculty members from Ohio public institutions, five ex-officio members and Ohio Department of Higher Education staff. The committee was charged by the Chancellor to develop expectations and processes that result in each University System of Ohio (USO) campus offering pathways in mathematics that yield (1) increased success for students in the study of mathematics, (2) a higher percentage of students completing degree programs, and (3) effective transferability of credits for students moving from one Ohio public institution to another.

The Steering Committee's resulting action plan was structured around five strategies:

- develop high-quality entry-level courses and pathways connected to coherent academic programs of study for students majoring in mathematics, other mathematics-intensive majors and academic majors that are not mathematics-intensive;
- develop policies and processes that foster effective transfer of course credits while encouraging course innovation on all public campuses;
- support constructive engagement of mathematics chairpersons and faculty within campus communities and across campuses to shape curricular policy, improve instruction and bolster student support and advising;
- develop high-quality measures for improving mathematics course offerings and instruction; and collect, analyze and share relevant data; and
- improve student success in college-level mathematics courses by aligning postsecondary expectations and high school practice.

According to Dr. Andrew Tonge, chair and professor of mathematics at Kent State University, and co-chair of the Ohio Mathematics Initiative's subgroup on alignment between secondary and postsecondary content and instruction, the underlying rationale for the initiative was "the clear correlation between success in a college student's first mathematics course and ultimate graduation from college." In Professor Tonge's words:

"We agreed on the need to ramp up success in mathematics at the college level. So we started by steering students away from remedial education, which led us to the state's remediation-free standards that are now being implemented on campuses across the state. Then we moved on to identifying learning pathways that may be more relevant to students – and more appropriate than the traditional College Algebra course given their learning and career objectives."

Today, five Ohio Mathematics Initiative subgroups are working to turn the words in the Steering Committee's final report and recommendations[2] into concrete action:

Subgroup 1: New and alternative pathways

Charged with exploring new and alternative college-level mathematics pathways for students with diverse programs of study and providing co-requisite strategies to students for whom a full sequence of remedial courses would be counter-productive

Subgroup 2: Revision of the Ohio Transfer Module (OTM) criteria

Charged with redesigning OTM course criteria and processes to focus on student learning outcomes, increasing departmental flexibility in determining pre-requisite courses and credit hour requirements for OTM courses, and defining what distinguishes a course as "college-level"

Subgroup 3: Communication, outreach and engagement

Charged with improving communication among mathematics faculty and stakeholders across institutions, encouraging and promoting faculty participation in professional group meetings, and engaging the larger mathematics community by disseminating information from the various Ohio Mathematics Initiative subgroups

Subgroup 4: Data collection, analysis and sharing

Charged with developing quality measures for improving student success in mathematics; then collecting, analyzing and sharing relevant data

Subgroup 5: Alignment between secondary and postsecondary content and instruction

Charged with conducting a national scan of best and promising practices designed to align secondary and postsecondary content and instruction; planning and hosting an Ohio Student Success Summit; studying the effects of Ohio's Remediation-Free Standards and the impact of institutional strategies to address these standards; and conducting regional meetings and workshops to generate ongoing conversations among secondary and postsecondary faculty, as well as state education policy leaders, about aligning K-12 and higher education curricula and policies, preparing and equipping new and existing math teachers, and building infrastructure to accomplish this work

[2] See Ohio Mathematics Steering Committee (2014). *Rethinking Postsecondary Mathematics: Final Report of the Ohio Mathematics Steering Committee* at https://ohiohighered.org/sites/ohiohighered.org/files/uploads/math/Math-FINAL.pdf

Featured Topics

The 2015 Ohio Student Success Summit had six objectives:

1. To build collaboration and communication and to achieve consensus among K-12 and postsecondary faculty on effective teaching methods, placement policies and practices
2. To access research and findings on effective practices for mathematics placement
3. To create a shared vision to improve student access to mathematics learning throughout high school and college
4. To maximize opportunities for higher education and K-12 faculty to learn from each other
5. To highlight effective high school to higher education practices to support the alignment of student learning expectations across the mathematics continuum
6. To engage counselors and advisors in dialogue focused on the importance of selecting the best emerging mathematics courses to support students' learning and career objectives

Reflecting each of these objectives, the Summit addressed a variety of significant issues and acknowledged a number of the recent advances designed to enable all students to master and appreciate mathematics. It is not feasible to explore all of those issues here. So this section of the report will focus on three topics that highlight the progress that has been made in recent years to enhance college and pre-college mathematics education. They also remind us that we have a long way to go.

Topic #1:

Ohio's New Learning Standards for Mathematics – Shifting education's focus from high school graduation to readiness for college and careers

More than a decade in development, new standards for mathematics – designed to establish more common ground for schools – are being implemented in Ohio and across the nation. Written under the auspices of the National Governors Association and the Council of Chief State School Officers, the new guidelines replace old standards that critics assert were shallow and repetitive, varying widely in quality, rigor and breadth of topics. As a result, the old standards – a hodge-podge of standards that dotted the education landscape from California to Maine – were seen as leaving students unprepared for success in college and careers, not to mention unable to compete with their peers in nations around the world.

Implementation of the new standards in mathematics and English Language Arts – known in Ohio as the *New Learning Standards* – has not been easy. Some have resisted on the grounds that the new standards are too tough. Others have argued they are the product of federal government pressures. Still others have directed their ire at the assessments that come with standards-based learning, pointing either to the time devoted to testing or to concerns about how and by whom the testing data will be "mined".

Yet, beyond the controversy that has been sparked nationwide, the new standards reflect three shifts in the teaching of mathematics:

> ***Focus.*** The new standards narrow ***the focus of teaching and learning*** by identifying key ideas, understandings and skills for each grade or course; they stress deep learning, which means applying concepts and skills within the same grade or course.
>
> ***Coherence.*** The new standards highlight ***progressions of learning*** within and across grades; they feature concepts and skills that are developed over a defined period of time.
>
> ***Rigor.*** The new standards feature ***conceptual understanding, procedural skill and fluency, and application.***

As described by Brian Roget, associate director of the Ohio Department of Education's Office of Curriculum and Assessment, and Dr. Bradford Findell, a mathematics faculty member at The Ohio State University, these shifts mandate substantive changes in the way students acquire mathematics knowledge and skills, including the following:

1. Making sense of problems and persevering in solving them
2. Reasoning abstractly and quantitatively
3. Constructing viable arguments and critiquing the reasoning of others
4. Modeling with mathematics
5. Using appropriate tools strategically
6. Attending to precision
7. Looking for and making use of structure
8. Looking for and expressing regularity in repeated reasoning

New perspectives on familiar content

*Illustrative of the new way of thinking brought on by Ohio's New Learning Standards is this new treatment of the **Pythagorean Theorem**, which is not just "$a^2+b^2=c^2$."*

- *Explain a proof of the Pythagorean Theorem and its converse*
- *Apply the Pythagorean Theorem to find the distance between two points in a coordinate system*
- *Prove theorems about triangles. This includes using similar triangles to prove the Pythagorean Theorem.*
- *Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems*
- *Derive the equation of a circle of given center and radius using the Pythagorean Theorem*
- *Prove the Pythagorean identity $\sin^2(\theta) + \cos^2(\theta) = 1$ and use it to calculate trigonometric ratios*

These practice changes were the starting point for Fred Dillon's Summit presentation,[3] which provided a national overview of the Common Core State Standards for Mathematics (CCSSM). Acknowledging that Ohio's New Learning Standards are closely aligned with the CCSSM, Dillon asked his audience this question, "What does it mean to be college and career ready in a Common Core world?"

Dillon, a mathematics educator who has taught at every level of the education system from middle school through college, admitted that the question is not easy to answer because there isn't widespread agreement on the meaning of "college and career readiness." Yet he offered several responses as he explored mathematics across the P-16 continuum.

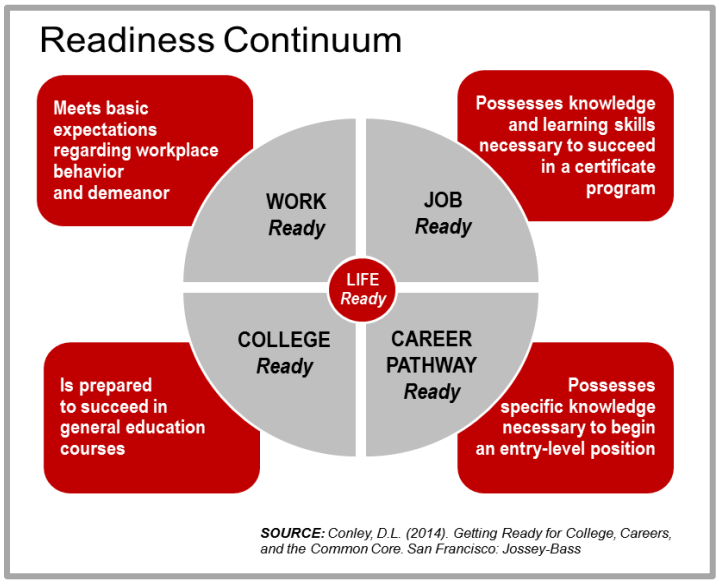
- First, with the new standards, educators will need to think about mathematics as a series of progressions – that is, topics across a number of grade levels, informed by an understanding of children's cognitive development and the logical structure of mathematics. For example:
  - ***Kindergartners*** will be exposed to the concept of cardinality, shapes and spaces, and the operation of whole numbers.
  - In ***first grade***, students will be developing understanding of addition and subtraction and strategies for addition and subtraction within 20; exploring whole number relationships and place value; and working linear measurement and measuring lengths as well as composing and decomposing geometric shapes.
  - By ***fifth grade***, students will be developing fluency with addition and subtraction of fractions, as well as understanding multiplication of fractions and division of fractions in limited cases (involving whole numbers and unit fractions); extending division to two-digit divisors, integrating decimals into place value, and developing understanding and fluency of decimal operations; and developing understanding of volume.
  - Further along the continuum, students in ***eighth grade*** will be formulating and reasoning about expressions and equations, modeling an association in bivariate data with a linear equation, solving linear equations and systems of linear equations; grasping the concept of a function and using functions to describe quantitative relationships; analyzing two- and three-dimensional space and figures using distance, angle, similarity and congruence; and understanding and applying the Pythagorean Theorem (irrational numbers).
- Second, with this learning continuum, the new standards maintain that all learning needs to do something new. Repetition of the same thing is not appropriate as students move from grade to grade. What is important is vertical integration; nothing is discrete, but grows across the curriculum.
- Third, the new standards are not the same as curriculum. They provide a base of information to be taught, but they do not tell educators how that content should be taught.

[3] For extensive background information and examples of Common Core State Standards for Mathematics (CCSSN) and Ohio's New Learning Standards, see Fred Dillon's Power Point presentation at https://www.ohiohighered.org/sites/ohiohighered.org/files/uploads/math/Student_Success_Summit/Mathematics%20Across%20the%20P-16%20Curriculum.pdf

- Fourth, with the new standards, teachers at all grades should see their classrooms as springboards to college (or to some other structured form of learning beyond high school). What this means is that the teacher's job – in first grade, in fourth grade, in seventh grade, in tenth grade and so on – is to get her or his students ready for college and careers, not to prepare them for high school graduation.

  Yet, what does "college and career readiness" mean in a Common Core world? The answer isn't as clear as one might think.

  - For Achieve, Inc., college and career readiness "means that a high school graduate has the knowledge and skills in English and mathematics needed to qualify for and succeed in postsecondary job training and/or education necessary *without remediation.*"[4]
  - Postsecondary instructors tend to value mastery of fundamentals over broad topic coverage. They expect incoming students to be able to solve complex problems using securely held knowledge and skills to flexibly apply what one already knows to a non-routine or complex problem.[5]
  - Professor David Conley advances a broader conception of college and career readiness, suggesting that students who are ready for college and career can qualify for and succeed in entry-level, credit-bearing college courses leading to a baccalaureate degree, a certificate, or career pathway-oriented training programs without the need for remedial course work. They can complete such entry-level, credit-bearing courses at a level that enables them to continue in the major or program of study they have chosen.



However, not every student requires the same proficiency in all areas to be ready. Student interests and post–high school aspirations influence the precise readiness profile that each student needs to demonstrate to be deemed fully ready for postsecondary studies. Therefore, a single score on a test given to high school students is not an adequate measure of college or career readiness because it does not take into account any possible individualization of the match between knowledge and skills on the one hand, and aspirations on the other.[6]

[4] http://www.achieve.org/college-and-career-readiness

[5] See the results of faculty surveys reported in *PARCC Model Content Frameworks, Mathematics Grades 3–11* (2011), p. 76.

[6] Conley, D.T. (2014). *Getting Ready for College, Careers, and the Common Core*. San Francisco: Jossey-Bass, p. 51

- Fifth, both secondary and postsecondary faculty should have a deep understanding of the new mathematics standards and practices and conduct open dialogues on how to deliver on these standards. The objective should be to bridge the gap between high school and college mathematics instruction and expectations as they relate to advanced thinking skills and academic behaviors. Specifically, they need to be focused on this variance:[7]

  - What percentage of mathematics educators reported their students are prepared for college-level work in mathematics?

High school mathematics instructors	89%
Postsecondary mathematics instructors	26%

- Finally, Fred Dillon pointed Summit participants to the National Center on Education and the Economy's assertion that learning standards need to be "raised" over time, even though "a large fraction of high school graduates cannot now do the work required of them in the first year of the typical community college program."[8] Among the Center's recommendations are that (1) a high priority should be given to the improvement of the teaching of proportional relationships; and (2) more emphasis is needed for percent, graphical representations, functions and expressions and equations."[9]

What is the anticipated benefit of these new mathematics standards, which have been described as the biggest pedagogic change in American education since John Dewey redefined the nation's approach to schooling in the early 20th century? Again, the answers are diverse.

- It is a process through which P-12 and postsecondary educators work together to improve their effectiveness in helping students acquire essential mathematics knowledge and skills.
- It is a mathematics curriculum that better connects to students' learning and career goals, and it is faculty members outside of mathematics departments who value the new standards because they enhance the education of their students.
- It is employers who can more easily find talented employees with the knowledge and skills needed in their work places.
- And it is students who are mathematically proficient with the ability to solve real-world problems because their mathematics education was better organized during the school year and across grades.

[7] ACT National Curriculum Survey (2009). Appendix B, Tables 6.6 and 8.9, p. 43

[8] National Center on Education and the Economy (2013). *What Does It Really Mean to be College and Work Ready?* Executive Summary, p. 8

[9] Ibid, p. 12

Topic #2:

Advancing the American Dream – Mathematics pathways that lead to higher levels of college readiness, participation and success

During its first days, the Ohio Mathematics Initiative was charged by the Ohio Department of Higher Education to develop high-quality, entry-level courses and pathways connected to coherent programs of study for students. In addition, it was directed to revisit transfer policies and processes that provide for effective transfer of course credits and encourage course innovation on campuses.

It should not be surprising, therefore, that the first Ohio Student Success Summit would be structured around the state's determination to design alternative mathematics pathways for both STEM and non-STEM postsecondary majors, to confront student persistence issues at public colleges and universities across the state, and to address concerns about the Ohio Transfer Module's guidelines for mathematics, statistics and logic.

The rationale for well-designed mathematics pathways is widely accepted. Throughout the Summit, there were comments about how undergraduate mathematics curriculum requirements are often shaped more by the weight of history than by advances in the discipline, the needs of employers or other users of mathematics or the interests of students. To be sure, students are not well served by traditional gateway courses and long sequences of remedial mathematics courses that are misaligned to their diverse programs of study. Yet, modernization of undergraduate mathematics is prudent for another reason: When mathematics is taught as decontextualized skills rather than concepts to be applied flexibly, students are not able to develop as problem solvers, and large numbers of students are turned off to mathematics. And the result is lower levels of college completion.

This is why the Ohio Mathematics Initiative is working with postsecondary faculty across the state to implement two changes designed to make mathematics more relevant and inviting for a broader range of students:

- ***To improve student success in entry-level courses by aligning mathematics to academic programs of study and by improving instructional delivery mechanisms***

  Ohio's public higher education institutions are developing and offering entry-level mathematics courses or redesigning existing courses to better align with the needs of students in clusters of academic programs (e.g., the social sciences, business and finance, allied health, and other STEM disciplines).

  In particular, departments are removing College Algebra as the default mathematics course for non-STEM majors. Additionally, mathematics departments are working to ensure that modern course instructional materials and delivery technologies – reflecting best and promising practices that support teaching and learning – are used in their entry-level courses.

- ***To develop, implement and evaluate co-requisite strategies to support underprepared students***

  For students underprepared for college-level work, traditional remediation courses have long been the default prerequisite to credit-bearing courses. Yet, there is growing evidence that for far too many students, postsecondary remedial courses are a dead end. An alternative solution is a ***co-requisite model*** through which students who demonstrate limited academic deficiencies are placed immediately into entry-level, credit-bearing college courses coupled with co-requisite support.

  For these students, co-requisite placement is the default instructional intervention with the length and structure of co-requisite support varied depending on the student's specific academic support needs. Presently, the Ohio Mathematics Initiative is disseminating co-requisite curricular materials to provide just-in-time support to students and resources for advisors placing students in co-requisites.[10]

The implications of these two actions were addressed by several Summit presenters and participants.

- Reporting that "Ohio is at the head of the pack" in implementing alternative mathematics pathways, Dr. Susan Wood said this work is not simply a postsecondary issue – that it demands precise and accessible advising at the secondary level and before to ensure that students are on track. Education is a tangled set of opportunities that is becoming even more confusing with added programs (such as Ohio's College Credit Plus) and multiple mathematics pathways. Choosing a college, selecting a course of study and launching a career path are not easy choices, particularly for first-generation students from families without a college-going tradition. These and other students need real-time information that is easy to understand and that will guide them in making appropriate choices.

  Nothing trumps advising. Yet, the advising and counseling offices on many high school campuses are understaffed and under-resourced – a limitation that needs to be addressed to ensure that students have access to accurate information about alternative mathematics learning pathways.

- Dr. Wood, a consultant with the Charles A. Dana Center at The University of Texas at Austin, also cautioned that the framing and implementation of mathematics pathways must be faculty driven. Faculty members must be engaged in every stage of the process to ensure alignment with the department's academic mission and capabilities. Sustaining pathways at scale requires a deep pool of faculty to teach the courses and to assist in communicating curriculum options to prospective students, as well as their colleagues in other departments and programs.

[10] See Ohio Department of Higher Education (2015). "Kent State develops alternative pathways and co-requisite courses" at https://www.ohiohighered.org/sites/ohiohighered.org/files/uploads/math/newsletters/FAST%20FACTS%202%20April%2013.pdf

- The building of mathematics pathways requires a clear understanding of what is, and what is not, a college-level course. This issue has been addressed through implementation of several changes to the guidelines for the Ohio Transfer Module (OTM) Mathematics, Statistics, and Logic. Key to these changes is the state's new definition of a "college-level" mathematics course, which Wood said "opens the door to pathways." That definition is:

  > *"A credit-bearing, college-level course in mathematics must use the standards required for high school graduation by the State of Ohio as a basis and must do at least one of the following: (1) broaden, or (2) deepen or (3) extend the student's learning."*

  Advanced by the Mathematics Chairs/Leads Network, this definition makes it clear that Intermediate Algebra is NOT considered a college-level course and, therefore, cannot be used to fulfill programs' general education requirements, including the requirements for two-year applied degrees. Yet, rigorous, college-level mathematics courses can take multiple forms (e.g., quantitative reasoning, modeling and elementary statistics), depending on the student's academic and career goals. In addition, embedded remediation/tutoring (including co-requisite models that allow students to close gaps in knowledge in a "just-in-time" manner, while taking credit-bearing courses) is a viable pedagogical approach.[11]

Supporting Multiple Pathways: An Update on Articulation and Transfer Policies

Early on the Summit agenda, Dr. Ricardo Moena and Professor Michelle Younker updated attendees on the state's Articulation and Transfer guidelines, which are designed to ease the way in which students can move to and from public colleges and universities by transferring credits and applying them toward the requirements of a postsecondary degree or certificate. Moena and Younker emphasized that the transfer of certain credits is guaranteed, which supports multiple educational pathways to meet the full spectrum of student needs and educational aspirations. Effective credit transfer practices enhance student mobility and increase both student satisfaction and degree completion.

Moena and Younker reported that the Ohio Mathematics Initiative had reviewed the OTM with a focus on ensuring the applicability of new and existing courses to majors and programs of study and on providing uniform standards while still accommodating course innovation. The relative value of Transfer Assurance Guides (TAGs) based on a specific set of topics and techniques, on the one hand, and student learning outcomes, on the other, was debated. The issues of prerequisite courses and the processes for approving courses and credits also were examined.

Recognizing the heightened importance of progressive, flexible and user-friendly policies and procedures for articulation and transfer, three changes were made, in addition to changes in the definition of a college-level course:

- The prescribed pre-requisite Ohio Transfer Module (OTM) requirements were removed for acceptance into the OTM Mathematics, Statistics, and Logic and OTM courses with learning outcomes.

[11] For more information, see Ohio Department of Higher Education (2015). "Intermediate Algebra is NOT a 'college-level' course" at https://www.ohiohighered.org/sites/ohiohighered.org/files/uploads/math/newsletters/Algebra_FAST_FACTS_1_March_12.15_FINAL.pdf

- The credit hour requirements were removed from OTM courses with learning outcomes.
- The OTM Guideline 4 was revised to focus on learning outcomes, instead of variable topics.[12]

As a closing note, Professor Younker emphasized that all of these changes were made to improve rates of student success. Yet, like other presenters who followed later in the day, she said that their implementation requires the collaborative action of secondary and postsecondary faculty. For example, pointing to the new definition of a college-level mathematics course, she asserted that faculty members in both sectors "need to start thinking outside the box about the progression of courses" and about what courses students should be taking given their range of interests from STEM careers to career-technical and other non-STEM pathways. She also said that postsecondary faculty need to be better informed about the high school curriculum so they can use Ohio's New Learning Standards as a basis for determining how they can "broaden" and "deepen" students' acquisition of mathematics knowledge and skills.

Topic #3:

The Story of Discovery – Ohio's leadership in mathematics education and research

In 1991, Ohio was one of the original 10 states to receive National Science Foundation (NSF) funding for a Statewide Systemic Initiative that promoted comprehensive reforms in mathematics and science education. Without imposing a single strategy for change, NSF's new funding initiative advocated for reforms that improved alignment among components of the education system, removed barriers to change and supported teachers' efforts so that all students would have a chance to master mathematics and science. It encouraged states to seek statewide change in pedagogy, including "hands-on" and "inquiry-based" education that would relieve students of the unproductive burden of rote learning.

For more than a decade, *Discovery* brought an infusion of talent – as well as a continuing stream of state dollars – into the existing educational system with three objectives: (1) initiate validated professional development models designed to build a critical mass of teachers who are knowledgeable in content and skilled in equitable and exemplary instructional practices, (2) develop an infrastructure to support those models and teachers, and (3) act as a catalyst for lasting systemic reform of the teaching and learning of mathematics and science.

The story of *Discovery* was one of substantive and sustained professional development for teachers, equitable instructional strategies, regional delivery and support, and public engagement in mathematics and science education. For almost a generation, it changed the landscape of mathematics and science education in Ohio, and it sparked a robust state/national research partnership that continues today.

National Science Foundation: Where discoveries begin

[12] For more information about these changes and the rationale for them, see Ohio Mathematics Steering Committee (2014). *Rethinking Postsecondary Mathematics* at https://ohiohighered.org/sites/ohiohighered.org/files/uploads/math/Math-FINAL.pdf

NSF is an independent federal agency created by Congress in 1950 to promote the progress of science; advance the national health, prosperity and welfare; and secure the national defense.[13] With an annual budget of $7.3 billion (FY 2015), it is the funding source for approximately one-quarter of all federally supported basic research conducted by the nation's colleges and universities. ***In many fields such as mathematics, computer science and the social sciences, NSF is <u>the</u> major source of federal backing.***

NSF's goal – discovery, learning, research infrastructure and stewardship – provides an integrated strategy to advance the frontiers of knowledge, cultivate a world-class, broadly inclusive science and engineering workforce and expand the scientific literacy of all citizens. The Foundation builds the nation's research capability through investments in advanced instrumentation and facilities and supports excellence in research and education in the fields of mathematics, science and engineering.

Why mathematics education is attracting funders' attention

"Mathematical sciences curricula need attention. The educational offerings of typical departments in the mathematical sciences have not kept pace with the large and rapid changes in how the mathematical sciences are used in science, engineering, medicine, finance, social science, and society at large."

"This diversification entails a need for new courses, new majors, new programs, and new educational partnerships with those in other disciplines, both inside and outside universities."

"As more and more areas of science, engineering, medicine, business, and national defense rely on complex computer simulations and the analysis of expanding amounts of data, the mathematical sciences inevitably play a bigger role because they provide the fundamental language for computational simulation and data analysis."

National Research Council (2013). *The Mathematical Sciences in 2025*. New York: The National Academies Press

Providing a national perspective on mathematics practices and pathways, Dr. Joan Ferrini-Mundy, assistant director of the National Science Foundation for education and human resources, told Summit participants that two trends are creating new opportunities in mathematics education – and for NSF-funded research. One is the changing nature of mathematics – significant changes in how the quantitative sciences are being used in science, engineering, medicine, finance, social science and society at large. The other trend is the changing nature of education, particularly the growing popularity of dual credit programs and the growing use of new instructional technologies in the classroom.

Dr. Ferrini-Mundy suggested that these two trends, in part, are driving NSF's mathematics education research agenda with emphasis in five areas:

1. modeling and computation;
2. data science – to meet the rapidly growing need for literate data scientists and managers;

[13] The National Science Foundation Act of 1950 (Public Law 81-507)

3. scaling – to bring success to scale, particularly in K-12 STEM education;
4. high school to college and career transitions – with a focus on mathematics preparation; and
5. equity and access – to ensure that ***all*** students have opportunities to learn mathematics

Ohio: Still at the heart of it all!

Dr. Ferrini-Mundy also told Summit attendees that Ohio – an early leader in mathematics education reform – is playing a major role in NSF-funded research. She identified numerous projects where Ohio's mathematics researchers, along with the colleges and universities where they work, are leading the way. These projects included the following:

Teacher Professional Development for Technology-Enhanced Inquiry to Foster Students' 21st Century Learning (Start date: September 1, 2014)
Investigators: Kathleen Koenig, Lei Bao, Kathy Wright, Janet Zydney and Casey Hord
Sponsor: University of Cincinnati

The goal of this Exploratory Design and Development Teaching project is to develop and evaluate a module for use in a 7th grade classroom that promotes student development of 21st century skills, with a particular focus on student development of scientific reasoning. The technology-enhanced curriculum will be designed to engage learners in deep and meaningful investigations to promote student learning of content in parallel with 21st century skills. The module will be designed using principles of inquiry-based learning as well as the principles of universal design for learning.

This project will contribute directly to the limited research on the interventions that impact teachers' capacity to provide high-quality 21st century STEM education to all students, with a specific focus on underrepresented minorities and learners with disabilities. The classroom setting for which the curriculum will be delivered is within an urban district that includes a large number of minority students and more than 20 percent of students with learning disabilities. The project will catalyze students' deep understanding of content knowledge while developing 21st century skills in parallel; hence, better preparing students for sustainable learning experiences into high school and beyond.

BCC Ohio Longitudinal Data Archive (Start date: September 15, 2013)
Investigators: Randall Olsen, Morton O'Kelly, Lung-fei Lee, Joshua Hawley and Stephanie Lavertu
Sponsor: The Ohio State University

By developing a shared interdisciplinary research platform across multiple universities and local and state agencies, the project (1) expands the community of users of the Ohio Longitudinal Data Archive; (2) establishes the legal agreements that facilitate access to

the data; (3) matches and integrates multiple forms of data; (4) improves the technical accessibility and usability of data; and (5) connects with researchers and organizations in other states that are pursuing similar goals to make cross-state comparisons easier to produce

The project expands the infrastructure in Ohio to conduct data-intensive research by developing an open portal that allows researchers to examine data archive documentation and codebooks to assess whether the data meet their research needs. The portal provides the structure that researchers can use to gain permission to utilize and securely access data. The project connects to multiple national efforts that support the use of data in education.

Mathematics Transitions in STEM Education (Start date: August 1, 2012)
Investigators: Rodney Null, Mary Ann Hovis and Beth Basista
Sponsor: Rhodes State College

This project involves high school, two- and four-year college and university educators along with their business and industry partners in developing a mathematics course for high school seniors with the overarching goal of improving student readiness for technical degree programs. Ongoing activities include intensive mathematics teacher professional development workshops and seminars and learning communities to ensure implementation of the course, which aligns with Common Core State Standards and Ohio's Mathematical Expectations for College Readiness. It also features a focus on actively engaging students in gathering, representing, analyzing and interpreting data through activities that emphasize application of mathematics in STEM fields.

National Center of Excellence in Welding Education and Training
(Start date: August 1, 2011)
Investigators: Monica Pfarr, Kenneth Smith, Kelly Zelesnik, Thomas Annable, Ernest Levert and Christopher Pollock
Sponsor: Lorain County Community College

The National Center for Welding Education and Training, also known as WELD-ED, is increasing the number of science and engineering welding technicians to meet workforce demands. The Center furthers comprehensive reform in welding education by providing technologically current educational materials and professional development opportunities to two-year colleges and other educational institutions. The focus is on welding technician education at community colleges, but secondary and university education are being advanced with a 2+2+2 model of vertical articulation.

The welding industry in the United States is economically large and technically diverse. It has documented substantial educational needs and considers technician education and training as essential to advanced manufacturing. The Center envisions education driven by industry needs through a network of nine regional partner colleges.

The project team represents five major corporations, four industry associations, 10 educational institutions, two government agencies, and one professional society. Collaboration with the Manufacturing Skills Standards Council and other employers and educational institutions assures that the education of welding technicians for the modern

workforce is the priority of the Center.

Teaching Practices That Support Fraction-Based Algorithmic Thinking
(Start date: August 15, 2010)
Investigator: Debra Johanning
Sponsor: The University of Toledo

The goal of the research is to identify core mathematical teaching practices that engage and support students in algorithmic thinking associated with fraction operations. The project has four objectives: (1) understand and document local instructional theories and routines of practice exemplary teachers use as they engage students in algorithmic thinking for fraction operations; (2) develop a prototypical model of core routines of practice generated from the work of these exemplary teachers; (3) design, pilot and study the usability of the prototypical model as a professional development tool with typical teachers; and (4) identify specific core routines of practice that are shown to be productive for use with typical teachers and explore ways of disseminating them at a larger scale.

The products of this work will be educational materials that can be used by other teacher educators to support the general population of teachers in this domain. These materials will identify core routines of practice associated with algorithmic thinking for fraction operations, and offer activities and tools to support their development in practice. Moving forward in this area is critical in the successful preparation of students for STEM careers.

Enhancing the Resource Center of the National Center for Manufacturing Education
(June 15, 2003)
Investigators: Steve Wendel, Bart Aslin, Jack Waintraub, Walter Buchanan
Sponsor: Sinclair Community College and other partners

The project developed a national clearinghouse of manufacturing education instructional materials. The Center used its web site as a primary national clearinghouse for exemplary manufacturing education materials. Materials were selected by peer review, categorized and incorporated into a searchable database.

The project disseminated effective models and pedagogical approaches in technical mathematics, technical science and manufacturing education. The peer reviewed instructional materials focused on integrating research activities into classroom teaching of manufacturing at the undergraduate level. This project involved collaboration between disciplines (technical mathematics, technical science and manufacturing technology) and several types of institutions including colleges, universities, industry and professional associations to improve manufacturing education.

As the Summit drew to a close, attendees gathered in small groups to explore a range of instructional, curriculum and student support issues. Informal and unscripted, these facilitated conversations gave attendees an opportunity to talk about issues of personal interest. Among the "take-aways" from these conversations were the following:

▶ *Breakout Group #1: Calculators*

The conversation focused on when faculty should allow students to use function, scientific or graphing calculators. Participants agreed that the culture of using calculators is being developed in the middle-school grades – too early in the view of many.

There was general agreement that many incoming postsecondary students have a good number sense, while others do not. Students without good number sense tend to rely more heavily on calculator usage. In addition, there was agreement that many nontraditional students who have not been in a structured learning environment for a decade or more are not comfortable with calculator use. For these students, calculator concepts must be reintroduced so they are not at a disadvantage when compared to traditional students.

Another point of agreement: When students come to college without knowing basic multiplication tables, the use of calculators can be condoned if students are expected to explain the process that is involved to solve a problem using the calculator as an aid. Finally, participants agreed that high schools must know – and let their students know – whether entry-level college courses and placement tests allow calculator use or not. In the final analysis, however, there was some disagreement about what level of calculator use is acceptable in mathematics classes.

▶ *Breakout Group #2: 21st Century Mathematics Skills*

This group focused on two questions: (1) what does "21st century mathematics skills" mean, and (2) what are participants doing to increase growth in the area of mathematics? The conversation focused largely on:

21st Century Math Skills

- Learning and innovation skills, critical thinking and problem-solving skills, communication skills (oral and written), and life and career skills

Growth in Mathematics

- Collaboration (mathematics, information technology and other areas are intermingling), the ability to explain problems (terminology and understanding are critical), molding into the way students want to learn (lab experiences), understanding technology and when to use it efficiently, and critical thinking and discovery skills

▶ *Breakout Group #3: Instructional Design – Embedding Mathematical Practices*

Participants in this group considered two questions: (1) how do K-16 staff and faculty utilize the Mathematical Practice Standards in their instruction to support alignment of student learning expectations from high school to postsecondary settings; and (2) how can K-16 staff and faculty continue the collaboration and communication established at the Summit to ensure high school graduates are college and career ready?

Consensus was not achieved on the first question. Most participants were unfamiliar with the standards and, therefore, acknowledged that they were not explicitly using them in their classes. However, these same participants said the standards were implicitly embedded in their philosophy of teaching mathematics. Those who were using the standards did so more explicitly in the early grades with usage diminishing in the later grades.

The standards were mostly unknown to higher education faculty. Several postsecondary participants said they'd had no professional development on how to embed standards into their courses. In order to develop a better understanding of how the standards can be used in instructional design and delivery, participants suggested the following: another student success summit; a mathematics symposium sponsored by the Choose Ohio First CAT scholarship; local professional development involving college faculty and area high school teachers; webcasts; activities funded through the Educational Service Center of Central Ohio grant program; and participation in the Quantway Institute.

The following suggestions were offered in response to the second question: conduct joint conversations for high school and college faculty; allow faculty to sit in on each other's classes; use college textbooks that reference the new mathematics standards; expand and improve teacher professional development; offer webcasts and collaborative discussion boards; use social media, chat rooms and workshops; blog; and establish Google Communities, Google Hangouts and periodic in-person meetings.

Breakout Group #4: 12th Grade Transition Courses

Among the key questions for this group were: (1) what should courses look like for 12th grade students; (2) how do we handle students who are college bound and those who are headed directly for the workforce (i.e., career-tech students); (3) with respect to 12th grade mathematics courses, how are we preparing students for the next step; and (4) can we provide remediation in high school before students move on to college?

Much of the conversation focused on mathematics courses that should or should not be part of the 12th grade curriculum. Beyond that, participants suggested that there needs to be some preparation for the computer skills necessary to take placement exams and college courses, better data are needed on student success once they leave high school and more reliable placement tests need to be identified and/or developed.

Opinions differed widely on how to handle students with varying levels of mathematics knowledge – particularly those who are not likely to be college bound. There also was a lack of consensus on the use of computer-based or online college courses. Supporters saw it as a good way to get students started in a mathematics program; others were concerned about students' ability to get others to do their work for them.

- ***Breakout Group #5: Advanced Credit Opportunities: College Credit Plus, Advanced Placement (AP) and International Baccalaureate***

This group focused on four issues: (1) advising students to select between Advanced Placement (AP) and College Credit Plus; (2) teacher credentials and training/additional coursework; (3) inconsistent training programs and practices in determining teacher qualifications for College Credit Plus; and (4) grade inflation by high school teachers in College Credit Plus courses.

Participants voiced a litany of concerns: teachers and counselors have widely varying opinions about what type of students should take AP courses/exams as opposed to college courses through College Credit Plus; parents are not receiving appropriate information and advising about AP or College Credit Plus opportunities; universities' graduate program/course offerings for teachers seeking College Credit Plus credentialing are inconsistent; and grade inflation (a result of high school teachers being pressured to give students high grades) will make it difficult for colleges and universities to monitor College Credit Plus practices.

- ***Breakout Group #6: Advising and Counseling in Mathematics Pathways***

This group explored ways in which Common Core (and Ohio's New Learning Standards) is changing the teaching and learning of mathematics, and how those changes impact advisors' and counselors' efforts to steer students into the right postsecondary pathways and programs.

The conversation reflected widespread concerns that students presented with so many pathways can have serious difficulty deciding on a mathematics course or program, particularly when they are not sure of their goals or plans, either in the classroom or in life. There was widespread consensus on several points: parents have to be involved in secondary advising so they understand the importance of mathematics pathways; advisors and counselors must be prepared to deal with students' "mathphobia" as they go from high school to college; too many high schools are teaching to standardized tests, not to the content that best prepares students for postsecondary coursework; and current approaches to remediation are not working.

One area where consensus was not reached was on the question of whether all high school students should have a base of Algebra II, regardless of his or her academic pathway.

- ***Breakout Group #7: Assessment***

Six questions were considered: (1) what do we assess, (2) how do we assess, (3) what do we do with the results, (4) what *should* we assess, (5) how *should* we assess, and (6) what *should* we do with the results?

The conversation dealt with the profusion of placement instruments and their relative merits. It was noted that (almost) all of them are algebra-based and, therefore, not suitable for many of the alternative pathways that are being developed. It was noted that much of what is assessed is procedural skill, while what is needed is assessment of conceptual understanding. The conclusion: It is time to find a different way to assess.

Virtually everyone agreed that postsecondary students should get mathematics "out of the way" early on. And there appeared to be consensus that GPA may be a good predictor of success in postsecondary courses.

▶ *Breakout Group #8: Shared Mathematics Interactive Session*

The focus of this conversation was on new ways to teach mathematics problems and some ideas for creating a new mathematics course. The focus was on polynomial factoring that was being included in a new textbook written by the group's facilitator, Mr. Bowen Kerins.

There appeared to be broad consensus and enthusiasm about how the "new style" of problems was set up for the textbook. The problems focused on factoring relating to Newton's Difference Formula and on how to put it in a more visual and easy-to-understand format.

Throughout the session, there was an emphasis on new course design principles:
(1) experience before formality, (2) general purpose tools, (3) textured emphasis, and (4) less time on convention and vocabulary. The conversation also reflected several ideas on general mathematics habits: conducting thought experiments, finding patterns, using representations, generalizing from examples and not expecting mathematics to make sense to students.

A Race Without a Finish Line: Ohio's unfinished mathematics education agenda

Nearly 25 years ago, Warren Schmidt wrote an insightful book about organizations' efforts to stay afloat in a tumultuous sea of constant change. In *The Race Without a Finish Line: America's Quest for Total Quality*, he told readers that organizations succeed and prosper when they embrace change and innovation – when they reject "good enough" ways of thinking and continually look for ways to improve what they do in all areas.[14]

What Schmidt said about organizations could be applied to the study of mathematics today. First, change is everywhere. As the Ohio Mathematics Steering Committee said in its 2014 final report:

> The opening years of the 21st century have been remarkable for the mathematical sciences. The list of exciting accomplishments includes "surprising proofs of the long-standing Poincaré conjecture and the 'fundamental lemma'; progress in quantifying the uncertainties in complex models; new methods for modeling and analyzing complex systems such as social networks and for extracting knowledge from massive amounts of data from biology, astronomy, the Internet, and elsewhere." For the non-mathematics world, these and other achievements can be seen in Pixar movies, hospital medical imaging and secure credit card transactions – all revolutionized by the strength and achievement of modern mathematics.[15]

Within the field of education, change isn't limited to the study of mathematics. In fact, with the implementation of the state's New Learning Standards for K-12 students, Ohio high schools are preparing to shift the meaning of a secondary diploma from a document that verifies the completion of a set of courses to a certificate of college and workplace readiness. Again, as the Ohio Mathematics Steering Committee pointed out, this will "create new demands for secondary and postsecondary curriculum alignment, and it will require changes in the way decisions are made (i.e., mechanisms for shared responsibility in this area). In addition, structural changes are being reflected in a growing bifurcation in high school mathematics outcomes (i.e., many graduates are being highly prepared with more students than ever before taking calculus, even as a much larger number of students are leaving high school underprepared for college mathematics)."[16]

To be sure, the reform of mathematics practices in Ohio and across the nation is a race without a finish line. Much has been accomplished, but so much more remains to be done. As Dr. Uri Treisman told participants at the end of the 2015 Ohio Student Success Summit, while Ohio may be leading the way in the development of multiple mathematics pathways, this is no time to be satisfied with past successes and to consider further effort unnecessary.

What should Ohio's next steps be?

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[14] Warren Schmidt (1992). *The Race Without a Finish Line: America's Quest for Total Quality*. Jossey-Bass.

[15] For more information about these changes and the rationale for them, see Ohio Mathematics Steering Committee (2014). *Rethinking Postsecondary Mathematics* at https://ohiohighered.org/sites/ohiohighered.org/files/uploads/math/Math-FINAL.pdf

[16] Ibid., p. 7

Dr. Treisman, professor of mathematics and public affairs at The University of Texas at Austin, and Dr. Susan Wood offered several suggestions, which Dr. Wood labeled “a call to actions.”

- ***Center on students.*** Make things easier for students to understand. Reform should create useful maps for students, and well-informed, fully-engaged advisors and counselors can be most helpful here.
- ***Engage faculty.*** Reform must be faculty driven, and that means both postsecondary and secondary faculty. It also means the engagement of faculty from other disciplines who depend on mathematics for the education of their majors.
- ***Broaden conversations across institutions.*** Keep an eye on transfer students who account for a majority of Americans who obtain a baccalaureate degree in the new world of student mobility. Since many two-year college students major in “I don’t know,” steps must be taken to ensure that transfer is effective, not just the acceptance of credits.
- ***Link with K-12.*** It is important to engage K-12 teachers and counselors early in the process.
- ***Leverage innovation.*** While Ohio has distinct pockets of innovation, concentrated efforts are needed to scale these up.
- ***Make effective use of data.*** Analytics really matter, particularly when the work is being done across boundaries. Better evaluation instruments are needed to tell whether or not what’s being done is working.
- ***Expect higher education to take the lead.*** By signaling the pace and direction of change, postsecondary faculty and institutions are powerful forces in K-12 mathematics education reform.
- ***Start and maintain good conversations.*** It takes practice to have good conversations, especially when they take place across boundaries. Several boundaries need to be crossed for effective mathematics reform: two- and four-year colleges and universities, geographical and demographic differences, teachers and academic support personnel, and more.

These are powerful reminders as Ohio confronts its still robust reform agenda to create viable learning pathways, build meaningful postsecondary gateway courses, establish appropriate learning progressions from grade to grade, bring down statewide policy and institutional silos, redesign instruction and delivery, get agreement on how standards will be used in the classroom and improve student advising – all intended to make mathematics more inviting for students and to strengthen students’ performance in a range of mathematical science courses at all levels.

Appendix: Speaker Profiles

John Carey

Mr. Carey was appointed Chancellor of the Ohio Department of Higher Education by Governor John R. Kasich in April 2013. As Chancellor, Carey oversees Ohio's public two-year and four-year institutions and Ohio Technical Centers, and provides policy guidance to the Governor and the Ohio General Assembly. Prior to his appointment, Chancellor Carey served nine years in the Ohio House of Representatives and eight years in the Ohio Senate. Chancellor Carey is a graduate of Ohio University with a degree in political science and is a first-generation college graduate.

Stephanie Davidson

Dr. Davidson is the vice chancellor of academic affairs for the Ohio Department of Higher Education. In that role, she oversees the units within the agency that: facilitate the creation of seamless, affordable academic pathways; ensure the quality and integrity of the postsecondary academic programming; and coordinate initiatives related to college access, readiness and educator preparation. Prior to joining the Department, Dr. Davidson served as a faculty member in the Department of Speech and Hearing Science at The Ohio State University for over 20 years. Dr. Davidson received her B.A. in audiology and speech sciences from Michigan State University and her M.A. and Ph.D. in audiology and hearing science from The Ohio State University.

Fred Dillon

Mr. Dillon is a mathematics educator, having taught middle and high school mathematics in Strongsville, Ohio. He also has taught college courses and provided professional development for mathematics educators. He is a former member of the Board of Directors for the National Council of Teachers of Mathematics, as well as the editorial panel of *Mathematics Teaching in the Middle School*. Mr. Dillon is a co-author of NCTM's *Principles to Actions* as well as several journal articles. Currently, he is a mathematics coach at Maple Heights and serves as an instructional facilitator with Cleveland's *Ideastream*.

Joan Ferrini-Mundy

Dr. Ferrini-Mundy is the assistant director of the National Science Foundation (NSF) for Education and Human Resources, a position she has held since 2011. Previously at NSF, she served as inaugural director of the Division of Research on Learning in Formal and Informal Settings. Dr. Ferrini-Mundy served as an ex-officio member of the President's National Mathematics Advisory Panel and co-chaired its Instructional Practices Task Group. Currently, Dr. Ferrini-Mundy is a co-chair of the White House National Science and Technology Council's Federal Coordination in Science, Technology, Engineering and Mathematics Education Task Force. Prior to going to NSF, she was a University Distinguished Professor of mathematics education at Michigan State University. Dr. Ferrini-Mundy holds a Ph.D. in mathematics education from the University of New Hampshire.

Bradford Findell

Dr. Findell serves as associate director of Mathematics Programs for Teachers in the Department of Mathematics at The Ohio State University, where he develops and teaches mathematics courses for teachers, with an eye toward the implementation of the Common Core State Standards. He was a member of the Mathematics Work Team for the Common Core State Standards and is past president of the Association of State Supervisors of Mathematics.

Bowen Kerins

An EDC Research Scientist and Senior Curriculum Designer, Mr. Kerins is a core member of the author team for the CME (Center for Mathematics Education) Project high school mathematics curriculum. He is experienced in current techniques and procedures used in the design, development and implementation of curriculum, curriculum-based professional development, instruction, and assessments. Since 2001, Mr. Kerins has taught and designed the curriculum for the Park City Mathematics Institute's program for high school teachers. He has a B.S. in mathematics from Stanford University and an M.A. in teaching secondary mathematics from Boston University.

Serita McGunia

Ms. McGunia is an assistant professor of mathematics at Cuyahoga Community College. Ms. McGunia recently served as the math faculty lead for the Cleveland Foundation's College Success Program Curriculum Alignment Project – a groundbreaking curriculum alignment project between Cuyahoga Community College and the Cleveland Metropolitan School District. She is actively involved with the Louis Stokes Alliance for Minority Participation program, where she serves on the selection, mentoring and cyber taskforce committees. Ms. McGunia is currently pursuing her doctorate in higher education administration at National American University.

Ricardo Moena

Dr. Moena is an associate professor of mathematics at the University of Cincinnati. He serves as the director of entry-level mathematics. His statewide leadership roles include the panel lead for the Ohio Articulation and Transfer Network's Ohio Transfer Module (OTM) Mathematics, Statistics, and Logic Faculty Review Panel and the chair of the Ohio Mathematics Initiative subgroup focused on redesigning the OTM course criteria and processes to focus on student learning outcomes, increasing departmental flexibility in determining prerequisite courses and credit hour requirements for OTM courses, and defining what distinguishes a course as college level.

Brian Roget

Mr. Roget is an associate director in the Ohio Department of Education Office of Curriculum and Assessment. Prior to joining the department, he served as a mathematics teacher in the Dayton Public Schools for 12 years. He completed his master's degree at University of Dayton and his baccalaureate degree at Cedarville University.

Richard A. Ross

Dr. Ross was selected by the State Board of Education as State Superintendent of Public Instruction in March 2013. Prior to his selection, he led Governor John Kasich's Office of 21st Century Education where he successfully moved several education initiatives through the legislative process. Previously, Dr. Ross was superintendent at Bryan City Schools, Ottawa-Glandorf Local Schools and Reynoldsburg City Schools. He has served as an instructor at Bowling Green State University and was a high school principal at Jonathan Alder Local School District. Dr. Ross earned an undergraduate degree in Social Studies, a master's degree in Educational Administration from The Ohio State University, and a Doctorate in Educational Administration from Bowling Green State University.

Andrew Tonge

Dr. Tonge serves as chair and professor of mathematics at Kent State University. His research and teaching interests include mathematics education and narrative methods. Dr. Tonge completed his doctorate at Cambridge University. He serves as a co-chair of the Ohio Mathematics Initiative subgroup focused on alignment between secondary and postsecondary mathematics content and instruction.

Philip Uri Treisman

Dr. Treisman is professor of mathematics and of public affairs at The University of Texas at Austin. He is the founder and executive director of the University's Charles A. Dana Center, an organized research unit of the College of Natural Sciences. He is actively engaged in the design of new Center initiatives and chairs the Center's senior leadership team. Before joining the Dana Center, Dr. Treisman was the E.M. Lang Visiting Professor of Mathematics and Social Change at Swarthmore College. In 1992, he was named a MacArthur Fellow. The Harvard Foundation of Harvard University named him "2006 Scientist of the Year" for his outstanding contributions to mathematics.

Susan Wood

Dr. Wood serves as a national consultant to the Building Math Pathways Initiative with the Charles A. Dana Center at The University of Texas at Austin. She is a charter faculty member and Professor Emeritus at J. Sargeant Reynolds Community College in Virginia. She joined the system office for the state's 23 community colleges in 2005. Dr. Wood retired in 2014 as the chief academic officer for the system after 40 years of service to Virginia's community colleges. She recently served as lead staff supporting the development of a statewide strategic plan for higher education for the State Council of Higher Education for Virginia. She holds degrees in mathematics and mathematics education from Virginia Tech and The University of Virginia.

Michelle Younker

Ms. Younker is an associate professor of mathematics at Terra State Community College. She serves as a co-chair of the Ohio Mathematics Initiative subgroup focused on Communication, Outreach, and Engagement.

Acknowledgments

The 2015 Ohio Student Success Summit was the product of many hours of brainstorming, planning and behind-the-scenes support from scores of individuals and organizations. We are most appreciative of the leadership and support provided by:

- John Carey, Chancellor, Ohio Department of Higher Education
- Richard A. Ross, Superintendent, Ohio Department of Education
- Stephanie Davidson, Vice Chancellor, Academic Affairs, Ohio Department of Higher Education

We would like to thank the following members of the Ohio Mathematics Initiative's Planning Subcommittee for their substantial efforts in framing the Summit, and for their ongoing commitment and genuine interest in the success of Ohio students in secondary and postsecondary mathematics courses:

- Sara Au, North Central State College
- Douglas Dosky, Worthington City Schools
- Jené Drage, Maumee High School
- Todd Eisworth, Ohio University
- Bradford Findell, The Ohio State University
- Kristin MacDonald, Kent State University
- Steve Phelps, Madeira City Schools
- Sandra Siegrist, Central Ohio Technical College
- Carl Stitz, Lakeland Community College

We are especially appreciative for the contributions of three individuals whose leadership and facilitation skills added significantly to the Summit's success:

- Rebecca Watts, Ohio Department of Higher Education, Summit Planning
- Barry Schieferstein, Ohio Department of Higher Education, Summit Logistics
- Kathryn Shipley, Ohio Department of Higher Education, Summit Logistics

We would like to acknowledge the wonderful support, including funding, and enthusiastic cooperation that we received from a number of partnering organizations:

- The Charles A. Dana Center at The University of Texas at Austin
- Complete College America
- Ohio Department of Education, Race to the Top
- Ohio Articulation and Transfer Network

And finally, we are grateful to the members of the Ohio Mathematics Chairs/Leads Network for their continuing efforts to create an infrastructure that allows for timely, meaningful cross-institutional communication.