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Future Directions for Mathematics Education Research, Policy, and Practice

2024 Convening Report

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Executive Summary

The Future Directions for Mathematics Education Research, Policy, and Practice convening identified critical areas of need and opportunity for progress in mathematics teaching and learning. Amidst concerns about declining mathematical achievement and persistent disparities in access to high-quality mathematics education, the convening aimed to define a vision for progress; identify opportunities to leverage new tools, technology, strategies, and partnerships; define current and emerging challenges; and outline concrete recommendations for research, policy, and practice.

The Future Directions convening brought together leaders across all levels of mathematics education and a range of related areas, creating a unique opportunity to draw on and integrate their combined expertise. Its content and activities centered around identifying challenges, opportunities, and recommendations for accelerating progress in mathematics education with a focus on

- K–12 mathematics teacher preparation,
- undergraduate mathematics teaching and learning, and
- meaningful K–12 career pathways.

The convening's strategic working group structure supported collaborative approaches to understanding challenges and barriers to progress and designing solutions to overcome them. Participants' discussions and recommendations centered equity with the aim of identifying systemic strategies for increasing diversity in the mathematical sciences and building more inclusive cultures and practices that support a sense of belonging for all learners.

Crosscutting Themes

Across all focus areas, participants emphasized a systemic need to reconceptualize many aspects of mathematics teaching and learning to create more **inclusive, equity-focused approaches to mathematics education**. Although there was widespread agreement on the need for school–industry partnerships to prepare students for modern careers and society, participants cautioned against over-alignment of the content and purpose of mathematics education with STEM careers, industry, and technology. Many believe that an overemphasis on career-related applications and utility can limit students' opportunities to explore and appreciate mathematics as a rich, meaningful part of their lives.

Another crosscutting theme was a **tension between the need for new ideas and the need to effectively scale and adapt successful, small-scale work** that has made or is currently making an impact in specific contexts. This, and many individual recommendations across focus areas, emphasized the importance of partnerships and collaboration across organizations, sectors, content areas, and levels of education. Two additional themes included the importance of **keeping students at the center of all aspects of progress** and the need to **elevate teaching and the teaching profession** across all education levels.

Recommendations

K–12 mathematics teacher preparation. Participants' recommendations for research related to teacher preparation include a focus on partnerships, collaboration, and alignment; mathematical knowledge for teaching; equity; teacher retention; and research methods and methodologies. Policy recommendations emphasize the importance of collective, coordinated efforts and the role of policymakers at federal, state, and local levels. Recommendations regarding practice focus primarily on building strategic partnerships to support teachers' development of the mathematical and pedagogical knowledge needed to provide all students with equitable opportunities to engage in meaningful mathematical learning.

Undergraduate mathematics teaching and learning. Recommendations for research on undergraduate mathematics education address assessment, scaled implementation, technology, the role and value of effective teaching in higher education, inclusive research, and systemic change. Several policy recommendations highlight the important role departmental and institutional policies and broader legislation play in this area. These recommendations focus on pedagogy and instruction, postsecondary mathematics pathways, and technology. Practice recommendations focus on improving and supporting pedagogy and instruction, professional learning, postsecondary mathematics pathways, technology, assessment, and the role of departments in driving progress.

Meaningful K–12 career pathways. Recommendations for research on meaningful K–12 career pathways focus on enhancing K–12 mathematics education, promoting diverse career pathways, and supporting students' academic and career success. Policy recommendations address incorporating STEM curricula, aligning mathematics pathways with career options, updating content standards, expanding evaluation measures, and fostering teacher competencies in data science and computer programming. Practice recommendations focus on creating student learning experiences that explore career opportunities and cross-sector partnerships that ensure these learning experiences are sustained.

Funding. Recommendations for funding organizations establish a need to support projects that scale and adapt successful initiatives, encourage partnerships that support diverse representation in research teams, prioritize equity in mathematics education, and fund research on AI and adaptive learning technologies.

Conclusion

The mathematical sciences play a critical role in American innovation and global competitiveness. Mathematical knowledge and skills are crucial for STEM disciplines, critical thinking, and problem solving in personal and civic lives. However, mathematics achievement in the United States has continued to decline since the COVID-19 pandemic, and disparities in educational opportunities persist. The evolving demands of industry and technology necessitate new partnerships and educational approaches to align learning outcomes, skills, degree and career pathways, and educational policies with workforce needs and interdisciplinary research. The Future Directions convening's recommendations provide a resource for future research, policy, and practice, with a focus on equity, collaboration, and innovation to prepare students for a rapidly changing world.

Background and Rationale

The mathematical sciences play a critical role in American innovation and global competitiveness. Opportunities for rich and rigorous mathematical learning at all levels build knowledge and skills that are crucial for all STEM disciplines and careers (Belser et al., 2018; Maass et al., 2019; National Research Council [NRC], 2013). They also promote critical thinking and reasoning that support problem solving in all aspects of our personal and civic lives (Szabo et al., 2020). However, recent national and international test scores show that mathematics achievement in the United States has continued to decline since the pandemic, and the country has fallen further behind other countries (National Center for Education Statistics [NCES], 2023; NCES, 2022; Organization for Economic Cooperation and Development [OECD], 2019).

Although there are examples of student achievement and educational innovation in the United States that are among the best in the world (OECD, 2019), broader disparities and disproportionate access to high-quality mathematics learning opportunities persist throughout the country (Rotermund & Burke, 2021; U.S. Department of Education Office for Civil Rights, 2018). This is impacted by many factors, including access to qualified mathematics teachers, resources, technology, and course offerings (NCES, 2022; Hung et al., 2020; Rodriguez, 2018). In addition to contributing to a national decline in mathematics achievement, these factors also lead to disproportionate representation among those pursuing degrees and careers in the mathematical sciences and other STEM disciplines (National Center for Science and Engineering Statistics, 2023). The resulting impact on diversity in the mathematical sciences and across STEM fields not only limits career options for underserved populations, it also prevents the United States from drawing on its full spectrum of talent and perspectives for ongoing efforts to improve prosperity, quality of life, global competitiveness, and national security (Cook et al., 2022).

As industry and technology have evolved, new solutions and opportunities have also brought challenges and concerns with regard to security, privacy, access, and equity (Archer & Prinsloo, 2019; Krumm et al., 2018). Addressing these challenges and concerns has relied heavily on the work of mathematicians (NRC, 2013). However, mathematics teacher education, the K–12 mathematics curriculum, and higher education degree programs in the mathematical sciences have not progressed at rates comparable to those of industry and technology. As a result, learning outcomes, skills, degree and career pathways, and educational policies have not remained well aligned with changing workforce needs or the increasingly interdisciplinary nature of research and development (Börner et al., 2018). This limits the extent to which

educators at all levels support workforce development and leverage the latest advancements to improve all levels of mathematics teaching and learning in the United States.

Over the past few decades, efforts to address these challenges have resulted in some level of progress but not nearly enough. However, recent advancements in industry and technology combined with access to data and information offer powerful new tools and opportunities to address these concerns in ways that have not been feasible previously. Such advancements demand new partnerships and collaborative approaches to both imagining and realizing the possibilities. They also require shifts in the culture of the mathematical sciences and new approaches to coursework and learning experiences that incorporate relationships with other disciplines, support cross-disciplinary career pathways, and create mechanisms to build collaborations among mathematical scientists, educators, and those in a range of other fields.

In response to these new opportunities, the **Future Directions for Mathematics Education Research, Policy, and Practice** (Future Directions) convening was collaboratively funded by the National Science Foundation's Division of Undergraduate Education (DUE), Division of Mathematical Sciences (DMS), and Division of Research on Learning in Formal and Informal Settings (DRL). The convening brought together leaders across all levels of mathematics education and a range of related areas, creating a unique opportunity to draw on and integrate their combined expertise. The convening's strategic working group structure supported collaborative approaches to understanding challenges and designing solutions to address them.

Convening activities were designed to inform future directions in research, policy, and practice in four significant ways:

- First, participants worked to define their **vision for progress** for multiple key areas of mathematics education.
- Second, they brought varying perspectives to identify **opportunities** to leverage new tools, technology, strategies, and partnerships to address challenges and support advancements in teaching and learning that are innovative, feasible, and designed to provide more equitable access to high-quality learning opportunities.
- Third, participants helped define current and emerging **challenges** that have previously restricted or could hinder future progress in mathematics education.
- Fourth, they identified concrete **recommendations** for programs, strategies, structures, policies, and investments that address the most pressing challenges and capitalize on exciting opportunities to accelerate advancements in mathematical learning for all students.

These improvements, achieved in an equitable way, are essential to the STEM innovation needed to continue to enhance U.S. prosperity, global competitiveness, and national security.

Convening Overview

Convening Focus Areas

The Future Directions content and activities centered around identifying challenges, opportunities, and recommendations for accelerating progress in mathematics education through improvement in the following four focus areas.

K–12 Mathematics Teacher Preparation: Participants identified strategies, structures, and supports needed to increase the number of K–12 mathematics teachers prepared with the pedagogical and content knowledge required to provide students with rich, rigorous, engaging, evidence-based mathematical learning opportunities. This area focused on both preservice teacher education and the professional development of current teachers, particularly those teaching out of field.

Undergraduate Mathematics Teaching and Learning: Recommendations in this area focused on strategies, structures, technology, and other resources that support efforts to improve teaching and learning in the first 2 years of undergraduate mathematics. This included developing mathematics faculty and other instructors' (e.g., postdoctoral fellows, graduate students) pedagogical content knowledge and improving instruction, assessment, and equity-focused postsecondary pathways with corequisite support. Attention was also given to developing essential mathematical knowledge and skills for our rapidly changing modern society.

Meaningful K–12 Career Pathways: Participants considered and proposed ways to enhance the capacity of K–12 schools and districts to foster meaningful pathways to a range of careers that rely on mathematical knowledge and practices. This included discussions and recommendations related to curricula, course structures and offerings, and school–industry partnerships that provide students opportunities to develop and apply their mathematical learning through solving real problems with tangible outcomes and engaging in collaborative research activities.

Systemic Equity-Focused Strategies for Increasing Diversity in the Mathematical Sciences: Discussions and recommendations in this area focused on systemic strategies and collaborations that ensure all students have access to equitable opportunities for high-quality mathematical learning. Participants worked to define the roles and responsibilities of K–12, undergraduate, and graduate education and its range of partners in improving diversity, equity, and inclusion in the mathematical sciences. This included making the structural and cultural

changes necessary to ensure these roles and responsibilities are achieved at each level. As a critical component of all STEM disciplines, focusing on systemic approaches to increasing equity in the mathematical sciences will support broader participation in STEM.

Convening Participants

The convening included 60 invited participants from 52 different organizations across the United States. They were strategically selected to ensure representation across all levels of mathematics and statistics education (early childhood through graduate education), career partners (business, industry, government, and nonprofits), technology and curriculum developers, and those involved with education policy at local, state, and federal levels. Participant selection also ensured broad representation regarding geography, gender, race and ethnicity, learning differences, accessibility, type of institution or organization (size, student population, public/private), and role within an institution, school, district, or organization (teachers, faculty, administrators, developers).

The facilitation team proposed a list of participants with expertise in one or more of the areas included below. External partners reviewed the proposed list and offered feedback and additional suggestions. The finalized list included participants with the following experience and expertise:

- K–12 district- or school-based instructional leaders, coaches, and teachers;
- undergraduate mathematical sciences faculty and scholars (2- and 4-year institutions);
- mathematical scientists, faculty, and scholars focused on mathematical sciences research;
- mathematics education faculty, scholars, teacher educators, and teacher workforce scholars;
- statistics and data science education faculty, scholars, and other specialists;
- computer science and computational thinking faculty, scholars, and other specialists;
- curriculum and education technology developers;
- STEM workforce (business, industry, government, nonprofit);
- policy partners (local, state, federal); and
- professional societies, associations, and philanthropic organizations.

Working Sessions

The multiday convening included a significant focus on small working group discussions and activities. Working groups were strategically constructed to ensure a diverse range of knowledge, expertise, and perspectives in each group. During the working sessions, participants identified their vision for progress in each focus area, discussed opportunities and challenges related to this vision, and established a series of actionable recommendations for research, policy, and practice. Whenever relevant, they also noted specific recommendations for funding organizations to serve as a resource when establishing priorities for future investments.

Synthesis of Discussions and Recommendations

Following the convening, the facilitation team synthesized the visions, ideas, and recommendations from all working groups. To ensure they captured the input appropriately, the facilitation team invited a subset of participants from each working group to review and provide feedback on the initial syntheses and drafts of these sections of the convening report.

Once the facilitation team incorporated the input from these virtual sessions, they shared a draft of the report with all participants, offering an opportunity for review and feedback. The following sections present a synthesis of participants' findings and recommendations.

Findings and Recommendations

This section documents discussions for each focus area. Each subsection conveys issues raised and recommendations made by convening participants. These include descriptions of participants' visions for progress, the opportunities and challenges that impact efforts to realize these visions, and recommendations for research, policy, and practice. This section also notes crosscutting themes and provides specific recommendations for other funding organizations.

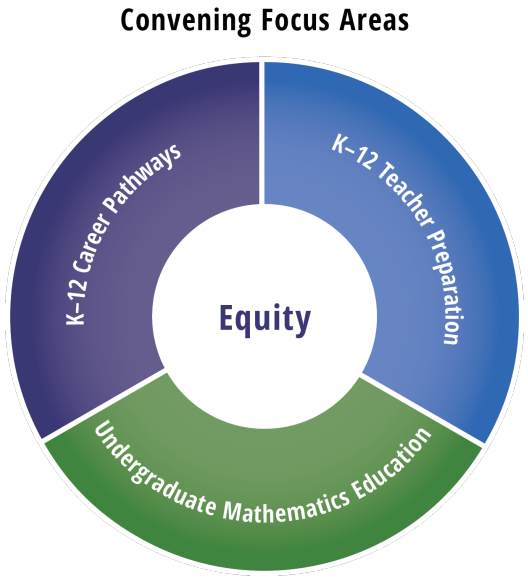
Vision for an Equity-focused Approach to Creating a More Diverse and Inclusive Mathematical Sciences Community

Originally, **equity-focused strategies for increasing diversity in the mathematical sciences** was a focus area for the convening. However, participants widely believed that this topic could not be disentangled from the other three focus areas. That is, they viewed equity as a core, integrated part of progress and action across all areas (Figure 1). Consistent with this belief,

although the final day of the convening was devoted to equity-focused strategies, participants addressed equity-related issues within the context of each of the other three areas:

- K–12 mathematics teachers preparation,
- undergraduate mathematics teaching and learning, and
- meaningful K–12 career pathways.

Figure 1. Integrating Equity as a Core Component of Each Focus Area



Proportionality was a consistent theme as participants discussed equity within the context of each of the first three focus areas. Participants articulated that a more diverse and inclusive mathematical sciences community would foster a teaching workforce that is representative of students' communities and include racial and gender representation across the mathematical sciences that is proportional to student demographics. They also described a vision for mathematical sciences content that better draws on and integrates funds of knowledge from a broader range of U.S. families, communities, and roles within society.

Participants' vision of equitable mathematics education included transforming curricula and associated school structures, classroom communities, and instructional practices. They emphasized that current K–12 and postsecondary curricula typically do not appropriately value the knowledge, ways of knowing, and ways of learning of many historically marginalized communities. Participants called for curricular revisions across all levels of mathematics education to ensure the mathematical sciences are responsive and relevant to students in ways that connect to their prior knowledge, experiences, and communities, which can foster a sense of belonging and empowerment. These revisions should also help to drive pedagogical progress

toward student-centered explorations of mathematics that are culturally responsive and relevant to all students' future careers and interests, not just for those planning to pursue STEM degrees and careers.

Participants regularly cited the need for cultural shifts that redefine the mathematical sciences in ways that emphasize a culturally grounded set of practices and rethink approaches to measurement of high-quality mathematics education. They noted that elements of innovative mathematical practices such as collaboration, communication, creativity, motivation, and persistence are rarely measured by current metrics of mathematics achievement, and many of these current metrics promote and reinforce inequities. They urged a shift away from test scores for placement and programmatic evaluation and toward metrics that honor students' identities and sense of belonging.

Participants' vision of equity-focused approaches to creating a more diverse and inclusive mathematical sciences community also involved adding and directing resources to address long-standing equity issues. Reforming mathematics curricula, pedagogy, and assessment in ways that make them more equitable requires significant investment in the education of teachers as well as school and district personnel. Teachers require training in culturally responsive and student-centered mathematics teaching and assessment. Administrators require professional learning to develop and use more equitable metrics to assess mathematical learning, identity development, and belonging. Participants noted that resources have historically been allocated in ways that exacerbate inequities. They also noted that investments in education often have the greatest benefit for the most advantaged students, perpetuating inequity rather than addressing it. Therefore, investments and advancements in mathematics education should focus on those who have historically been marginalized and include provisions that ensure they can access these opportunities, inclusive educational cultures, and communities that foster a sense of belonging.

Participants' recommendations for achieving this vision are integrated within each of the following sections on K–12 mathematics teacher preparation, undergraduate mathematics teaching and learning, and K–12 career pathways.

K–12 Mathematics Teachers Preparation

As participants discussed the preparation and continued professional learning of K–12 teachers, they identified features of instruction that should be at the center of improvement efforts. Participants argued for culturally responsive mathematics instruction that is relevant to students' experiences and aspirations. They described instruction that draws on students' funds of knowledge and connects to their lives, values, interests, communities, and career trajectories. This framed discussions and recommendations for K–12 teacher preparation.

Vision for Progress

Participants described progress in K–12 mathematics teacher education as ensuring equal access to high-quality instruction across contexts and populations. They believed this requires more mathematics teachers who represent the diverse communities served by education in the United States and more teachers equipped with the knowledge and tools required for higher-quality instruction, including

- greater knowledge of the mathematics content they teach,
- deeper understanding of pedagogy that is equity oriented and relevant for all students, and
- effective use of technology for instruction and as a mathematical learning tool for students.

This vision requires **changes in the teaching profession**. Participants emphasized that teachers need greater respect and support along with the freedom to be creative and exercise their professional judgment. To ensure their instructional practices maintain a level of quality aligned with professional standards, they must also be seen as professional learners with the resources and incentives needed for continuous improvement. Teacher observations and quality metrics should serve to identify professional learning needs and chart a course for growth rather than be solely evaluative. Teachers should also have well-supported structures and opportunities for professional learning communities. Additionally, increases in teacher pay combined with a reduction in overall workload are critical to preventing burnout and allowing opportunities for collaboration and continued professional development.

Participants also believed that making **teacher education programs more accessible** is essential to increasing recruitment and building a more demographically representative workforce. Increasing the accessibility and benefits of entering the teaching profession while decreasing the cost and other barriers will attract a more diverse teacher workforce. This requires more alternative pathways and more debt-free options for teacher preparation. Participants identified low-cost or paid school- and community-based programs as important for enabling teacher candidates with more diverse backgrounds to enter the profession, contributing to a representative teacher workforce.

Additionally, improvements to **undergraduate mathematics education and teacher education programs** are critical for progress. These include more opportunities for preservice teachers to gain school- and classroom-based teaching experience. They also require stronger partnerships between undergraduate faculty in the mathematical sciences and K–12 mathematics teachers. Such partnerships can help undergraduate faculty better understand the mathematical knowledge needed for teaching K–12 students and make stronger connections to K–12 content in undergraduate coursework. K–12 mathematics teachers can also help undergraduate faculty

build proficiency with active pedagogies to improve pedagogical modeling for undergraduates in K–12 teaching pathways, including equity-focused practices.

Opportunities and Challenges

The most widely cited opportunity for this vision of progress was emerging support for strategic partnerships. Partnerships are critical to developing a cohesive systemic vision of mathematics education centered on active and equitable learning experiences.

Participants discussed partnerships between undergraduate mathematics educators, K–12 mathematics educators, teacher educators, government and industry professionals, and community organizations. Partnerships between undergraduate institutions and K–12 schools could ensure that teachers are equipped to prepare students to pursue advanced studies in the mathematical sciences, including research and interdisciplinary studies. Such collaboration can also support improvements in pedagogy (e.g., student-centered instruction) across levels and help undergraduate teacher education programs appropriately develop mathematical knowledge for teaching (MKT). Input from private and public sector partners can ensure that MKT includes knowledge of skills and technology needed for problem solving, innovation, and global competitiveness. Additionally, industry partners can provide resources to enhance mathematics teacher education, including recruitment and support of teachers of color.

Participants identified several other potential opportunities that use partnerships in order to grow and leverage the current body of research on equitable mathematics teaching. Researchers and practitioners have developed pedagogical tools for culturally relevant mathematics teaching and evidence-based approaches to supporting diverse learners, including multilingual students and students with disabilities. Professional organizations such as the Association of Mathematics Teacher Educators (AMTE), the National Council of Teachers of Mathematics (NCTM), and TODOS: Mathematics for ALL are positioned to identify and support new ways of curating, disseminating, and supporting the application of research in order to directly shape practice for teachers and teacher educators. Minority-serving institutions offer opportunities to more intentionally develop and support outreach strategies to recruit students of color into teaching. Two-year colleges, community- or school-based programs (often called “grow-your-own” programs), and no-cost teacher preparation programs also offer opportunities to reduce barriers to entry into the profession.

Artificial intelligence (AI) also featured in participant discussions for its potential as a tool for mathematics teachers if used in ethical and equitable ways. Increasingly, AI tools can aid mathematics teachers in lesson planning and grading. As these tools continue to develop and teachers learn to use them for student-centered, relevant, discourse-laden instruction, they offer a means for improving the quality of instruction without increasing teacher workload. However, such advances typically disproportionately serve students in well-resourced schools and communities, perpetuating inequity. For AI to advance equity, investments in development and implementation need to prioritize schools and communities that have disproportionately

lower access to resources. This includes representation among developers, professional learning for teachers, and funding for access to the technology and its required infrastructure.

The challenges in mathematics teacher education were foreshadowed in participants' vision for progress. Improvements in K–12 mathematics instruction and teacher education are interconnected. Students without access to high-quality K–12 mathematics instruction are less likely to develop the deep mathematical understanding necessary to become effective mathematics teachers and mathematics teacher educators. This is especially detrimental for students of color in schools with limited course options and other gatekeeping structures that impact their mathematics education. It can also further erode public appreciation for mathematics and respect for mathematics teachers, which contributes to teacher attrition and loss of intellectual capital among the teacher workforce, particularly among teachers of color.

Even student excellence in K–12 mathematics does not guarantee a sufficient number of qualified, diverse mathematics teachers. Insufficient pay for teachers means that those who succeed in mathematics have more lucrative career options in which they do not have to face the current challenges of K–12 teaching. Low pay communicates a devaluation of the profession and contributes to workforce attrition. Insufficient resources in teacher education programs create barriers to the profession, particularly for those of low socioeconomic status. Furthermore, the pool of teacher education program applicants is disproportionately white, which may discourage prospective teachers with more diverse racial and ethnic identities from pursuing a career in which they may feel like an outsider.

Participants also noted challenges with teacher education program (TEP) quality. There is wide variation in the working conditions in schools and in the resulting experiences of teacher candidates learning to teach in schools. Some TEPs are student-centered and equip candidates with culturally relevant mathematics teaching practices and student-centered pedagogy, but this is by no means ubiquitous. Many TEPs are out of touch with the needs of the communities their teachers serve or the realities they will face in their classrooms. This is particularly true of alternative teacher education programs, many of which inadequately prepare mathematics teachers with the content knowledge and pedagogical skills needed for effective instruction.

Recommendations for Research, Policy, and Practice

Participants identified recommendations for research, policy, and practice related to K–12 mathematics teacher preparation. In some cases, these recommendations have clear actors, whereas others require coordinated efforts (e.g., state and local education agencies; higher education institutions and faculty; K–12 school and district administrators, educators, parents, and families; community organizations and leaders).

Additional recommendations for funding organizations can be found at the end of this report in the section "Recommendations for Funding Organizations."

K–12 Mathematics Teacher Preparation: Research Recommendations

Participants' recommendations for research related to K–12 teacher preparation (TP-R) span a series of themes, including partnerships, collaboration, and alignment; mathematical knowledge for teaching; equity; teacher retention; and research methods and methodologies.

Partnerships, Collaboration, and Alignment (PCA)

TP-R-PCA 1: Identify and study current teacher education models that exemplify effective partnerships. Research is needed to better understand the partnerships that support effective teacher education models, vital elements of implementation, and conditions needed to scale such models. Such partnerships may include local education agencies, state education agencies, institutes of higher education, community organizations, and other relevant partners.

TP-R-PCA 2: Expand partnerships that involve researchers, practitioners, and policymakers in all stages of research design, implementation, and dissemination. Strategic partnerships can help ensure actionable implications for practice and policy. This includes research on the following:

- Professional learning structures and content that impact teacher practice in ways that support cognitive and sociocultural learning.
- Effective instructional practices (as demonstrated by a range of student outcomes) and efforts to scale these practices across contexts with expansive models of efficacy. This should specifically attend to how research on high-quality instruction is adapted for effective implementation across contexts, including transferability across communities and adaptations required of an individual teacher across classes and school years.
- Equitable teaching practices that ensure all students in all classrooms, schools, and communities have access to high-quality mathematics instruction and the professional learning required to support these practices.
- Ways in which teacher practices that are considered relational or affective in nature (e.g., taking interest in students' lives, believing in students) impact student achievement and equitable outcomes. This is essential to emphasizing the value of such strategies across all levels of education (early childhood to graduate education).
- Successful models for integrating mathematics with other disciplines, including the affordances and constraints on students' opportunities to learn mathematics and professional learning for teachers to successfully teach across disciplines.

Mathematical Knowledge for Teaching (MKT)

As technological innovation continues to rapidly reshape our society and lifestyles, research on how modernizing the mathematics curriculum impacts MKT and teacher education is essential.

TP-R-MKT 1: Identify mathematical content that is important in modern industries and society and examine how it changes over time. Given that the knowledge and skills required by rapidly changing technology and workforce demands will continue to evolve, researchers should expand their focus beyond what mathematical content is important at a particular moment in time and examine the factors that shape how this content evolves (e.g., key drivers, time frames). This will help the field anticipate future developments and avoid systemic change efforts that may ultimately have short-term relevance.

TP-R-MKT 2: Balance career-oriented content with mathematical learning experiences that are rich and meaningful to all students. Practitioners, researchers, and other partners should collaboratively create and study models, structures, and resources that include modern career-oriented mathematical content and engage all students with mathematics in rich and meaningful ways, regardless of whether they plan to pursue a STEM career.

TP-R-MKT 3: Consider the extent to which curricular changes aligned with new technology and industry demands mean that teachers' content knowledge must continually evolve. Without substantial time, resources, and support, it is unreasonable to expect mathematics teachers to continually provide students with the changing knowledge and tools needed to support advances in industry and society. Researchers, practitioners, policymakers, and other strategic partners should work together to study professional learning models, structures, and resources that effectively support teachers' implementation of new mathematical content and practices. This should include ways to build and leverage effective co-teaching models that support incorporation of changing content requirements.

TP-R-MKT 4: Continue to study the impact of specific postsecondary mathematical sciences content, coursework, and learning experiences on elementary and secondary teachers. There is a need to continue to expand research on the ways in which specific advanced mathematical learning experiences shape preservice and practicing teachers' knowledge and appreciation of mathematical content, mathematical practices, the nature of mathematics, and the utility of mathematics. This research is essential for supporting the standards and policies that determine the mathematical content and learning requirements for TEPs. It is also important for guiding TEP development and promoting productive collaboration between those in the mathematical sciences and teacher education faculty.

TP-R-MKT 5: Build an evidence base to support teachers' development of positive mathematical identities and prepare them to foster positive mathematical identities in their students. Teacher education would benefit from research that focuses explicitly on teachers' development of positive mathematical identities and their ability to help students do the same. This research should include identifying effective structures, supports, opportunities, and experiences in preservice teacher education and professional learning. Participants noted that this was especially important for teachers at the elementary level and for ensuring teachers are equipped with the knowledge and practices needed to foster positive mathematical identities in students of color, students with disabilities, and students who are part of other groups that are underrepresented in STEM.

TP-R-MKT 6: Support teachers' ability to make data-informed instructional decisions. Modern learning tools and technologies make it increasingly important for teachers to know how to interpret student data and make data-informed decisions about their instructional materials and practices. Research in this area should investigate what knowledge teachers need to utilize student data ethically and equitably and effective ways of developing this knowledge for both preservice and practicing teachers.

Equity-Focused Teaching (EFT)

TP-R-EFT 1: Advance theory and practice that supports inclusive and equitable systems at scale. To build shared understanding of equitable teaching practices and the structures needed to support them, strategic research partnerships should strive to better understand, document, and describe inclusive and equitable systems at scale (e.g., development of theories of action, empirical studies of holistic systems).

TP-R-EFT 2: Elevate different bodies of equity-focused research in ways that demonstrate the complex nature of the current knowledge base for equitable teaching. Equity-focused research and dissemination activities should emphasize the complex nature of equitable teaching practices by demonstrating the need to consider different studies, methods, and implications for practice with different student populations (e.g., racial and ethnic groups, multilingual learners, students with disabilities).

TP-R-EFT 3: Distinguish between teaching practices that historically have been considered effective and practices that are equitable. Research and dissemination activities need to articulate ways in which certain practices may be effective for specific student populations and contexts but not necessarily inclusive or equitable beyond these particular groups or contexts. One particular example of such a need is establishing a set of equitable mathematics teaching practices for students with disabilities.

Retention of Teachers (RT)

TP-R-RT: Conduct local- and regional-level research on the retention of teachers. Research on retention should focus on understanding why teachers leave the profession, how this differs across contexts, and what supports would help them stay. It is important to expect associated research findings to vary in ways that require studies at local and regional levels. These studies should include demographic data to understand attrition associated with race, ethnicity, gender, and other teacher and student characteristics.

Research Methods and Methodology (RM)

Participants expressed concerns about "gold standard" methods becoming narrowly focused on quantitative methods and restrictive experimental studies such as randomized controlled trials. These concerns are reflected in the following recommendations.

TP-R-RM 1: Establish mechanisms that support and maintain the quality and rigor of different types of research methods and what constitutes evidence. Research methods should continue to evolve in ways that are culturally responsive and inclusive. This includes recognizing the value of evidence that is local and contextual and grappling with questions about whether there are distinctions between the type and nature of evidence that should inform investments, structures, programs, policies, and practices at the local, state, and federal levels.

TP-R-RM 2: Develop and evaluate inclusive, practical measures and data collection processes. Inclusive data collection tools and processes are essential to ensuring all students are appropriately represented within research. Diverse, practical measures should attend to the complex nature of equitable instruction and include affective outcomes.

K–12 Mathematics Teacher Preparation: Policy Recommendations

Participants made several policy recommendations related to the preparation of K–12 mathematics teachers (TP-Pol). Although they did not consistently identify relevant agents for such policy-related actions, they emphasized the importance of collective, coordinated efforts and the role of policymakers at all levels (state, local, federal).

TP-Pol 1: Develop and enact policies that elevate the mathematics teaching profession. Collective efforts (e.g., grassroots advocacy; state, local, and federal policymaking) to boost public perception of mathematics teaching and the broader teaching profession could include

- leveraging a range of popular media outlets to publish and promote positive narratives about teaching and teachers (e.g., social media, streamed TV series);
- supporting grassroots organizations focused on teachers and teaching;
- encouraging and incentivizing mathematics students to consider teaching as a career choice; and

- developing more opportunities for growth and promotion within the teaching profession.

TP-Pol 2: Decrease the cost of entering and thriving in the teaching profession. Policymakers and organizations such as professional societies can help reduce cost barriers with policies that

- make the cost of teacher preparation programs proportional to salaries in the area or free in exchange for future classroom service;
- provide easily accessible programs that reduce teachers' student loan debt;
- provide more time and incentives for continuing professional learning, including free NCTM memberships during a teacher's first 5 years; and
- increase teaching salaries and opportunities for career progression to attract and retain more mathematics teachers.

TP-Pol 3: Pursue coordinated policy strategies that directly enhance teacher preparation. Examples of such efforts include

- coordinating state and federal policies to support professional learning;
- providing postsecondary pathways to support those learning to teach mathematics; and
- establishing clear transfer agreements between institutions so that students on a trajectory to teach mathematics can stay on that path even with a transfer.

K–12 Mathematics Teacher Preparation: Practice Recommendations

Similar to many of the research recommendations, the teacher preparation practice recommendations (TP-Prac) focus primarily on building aligned partnerships. These strategic partnerships are critical to supporting teachers' development of the mathematical and pedagogical knowledge needed to provide all students with equitable opportunities to engage in meaningful mathematical learning.

TP-Prac 1: Create more opportunities for intentionally designed interactions between mathematical sciences researchers, teacher educators, and K–12 teachers. Establish and implement intentionally designed, evidence-based facilitation strategies to enable mathematical sciences researchers and mathematics teacher educators to bring their unique expertise to shared conversations about the preparation of K–12 mathematics teachers. In addition to bringing uniquely valuable experience and expertise to critical conversations about teacher development, each group can learn from the other in ways that can improve their own practice and enhance how they engage with current and future teachers. Such discussions should also be expanded to include K–12 teachers, with careful attention to managing power dynamics and affirming the value of differences in the specialized mathematical knowledge of all involved.

TP-Prac 2: Build partnerships between traditional and alternative licensure programs that improve options and access to teacher education. Those involved with traditional and alternative licensure programs should work together to provide new structures and options that improve access to teacher education, especially for teacher candidates of color. Such collaboration should focus on creating flexible opportunities while ensuring that alternative licensure programs operate in alignment with AMTE standards. This may include integrated structures that allow flexible enrollment and completion across programs (e.g., ensuring course timing works with the schedules of practicing teachers, advancing mathematical content knowledge of those in alternative licensure programs).

TP-Prac 3: Create opportunities for supported, facilitated collaboration between K–12 mathematics educators and special education teachers, leaders, and researchers. K–12 mathematics teachers and leaders should work closely and consistently with special education colleagues to make mathematics education more inclusive for students with disabilities. These collaborations should be supported with time, resources, and facilitation. Parallel partnerships should also be established between teacher education and special education programs.

TP-Prac 4: Establish and enact evidence-based practices that help administrators and teachers better understand each other's roles. Ongoing interactions between administrators and teachers can have mutual benefits. For example, administrators may need help learning about inclusive teaching practices and how to incentivize teachers' use of these practices. Teachers can also benefit from understanding the factors that drive administrators' responsibilities and decision-making so that they have a voice in determining equitable measures of learning and have opportunities to develop leadership skills. The former NSF Math and Science Partnership program is an example of ways in which funding programs can encourage these collaborations.

TP-Prac 5: Create and support opportunities for teachers to partner with researchers to implement and monitor equity-focused research recommendations in their classrooms. Teachers need ways to easily access and identify evidence-based practices they want to enact in their classrooms (e.g., mathematical practices, culturally responsive teaching). They also need opportunities and resources to initiate partnerships with researchers to support their implementation of these practices, monitor the effectiveness and impact of these practices in their schools and classrooms, and share their work with others.

TP-Prac 6: Create K–12 and postsecondary educator exchanges or site visits. Engaging with higher education faculty, courses, and cultures at different institutions can help K–12 teachers understand the postsecondary experiences for which they are preparing their students. These experiences can also help higher education faculty reconnect with the learning environments their students come from and for which they are preparing future teachers. Additionally, they give all parties an opportunity to share their insights on content and pedagogy. Short-term visits or longer-term residencies should be structured to fit within a teacher's schedule and have established practices or resources (e.g., observation guides, discussion guides) to ensure productive, purposeful engagement.

TP-Prac 7: Develop programming for K–12 teachers in organizations where students may pursue careers or utilize their mathematical learning to solve authentic problems. Teachers need exposure to the ways in which mathematics is used in industry, government, nonprofits, and other organizations (e.g., museums) to be able to share this information with their students. Engaging with these organizations can help teachers bring more relevance to the mathematics they teach and support their students' development of essential mathematical practices.

TP-Prac 8: Provide professional learning and resources that develop the communication and collaboration skills needed to build and sustain equitable partnerships. Critical components of partnership-focused professional learning include creating inclusive structures, managing power dynamics, and ensuring bi-directional engagement and mutual benefits.

TP-Prac 9: Increase teachers' access to professional learning and practical resources focused on building inclusive mathematics classroom communities. Along with content-focused professional learning, teachers need mathematics-specific professional learning, resources, and classroom-based support for building inclusive classroom communities that foster productive mathematical learning, a sense of belonging, and positive mathematics identities for every student. It is essential for teachers to understand the specific need for this in mathematics education and be able to recognize critical features of inclusive mathematics classrooms.

Undergraduate Mathematics Teaching and Learning

Discussions of improving undergraduate mathematics teaching and learning focused primarily on those who have been traditionally underserved in and by postsecondary mathematics education, particularly in their first 2 years of undergraduate studies. Participants prioritized decreasing course drop, withdrawal, and failure rates. Improving undergraduate mathematics education for these students requires a major culture shift in how mathematics is understood and assessed, how mathematics departments conceptualize the purposes of mathematics coursework, and how institutions of higher education understand the value of teaching.

Vision for Progress

Participants identified a set of key outcomes in their vision for progress in undergraduate teaching and learning in the mathematical sciences, with a focus on the first 2 years of postsecondary education:

- Students enrolled in courses and programs in the mathematical sciences, along with the faculty who serve them, are representative of the population in terms of race, gender, sexual identity, linguistic identity, ability, and socioeconomic background.

- Curricular developments and course offerings reflect the evolving priorities and advances of modern society and improve alignment between K–12 and undergraduate mathematics.
- A high percentage of students pass their mathematics courses in the first 2 years.
- Students believe their mathematics courses were an asset to their education and their lives.

Participants discussed several levers for improvement that can support this vision. **Improving instructional practices** was identified as the most important lever in achieving these outcomes. Increased student-centered teaching in mathematics courses that includes practices such as collaborative and active learning, culturally responsive and sustaining practices, and social–emotional learning supports would contribute to the outcomes. These instructional practices would help build community and sense of belonging among students and faculty, shifting the culture of using mathematics for gatekeeping or weeding out students to a culture of support and inclusion. Structural changes such as reducing large lecture sections and supporting cross-disciplinary and cross-sector (K–12 teachers and higher education faculty) partnerships and collaborations would also contribute to achieving these goals.

Another important lever is **elevating the value of teaching in higher education**. Tenure, promotion, evaluation, and incentive structures that value excellence in teaching in the same ways they value excellence in research are essential to supporting this progress. Faculty and instructors who are not on a tenure track (e.g., adjuncts, teaching assistants) should be valued, supported, and incentivized to improve their practice.

Additionally, **modernizing undergraduate mathematics curricula and course offerings** is crucial to ensuring alignment with K–12 education, the needs of other disciplines, and the career goals of students. This type of progress requires faculty to better understand how the mathematical sciences are used in various fields and creation of curricular materials that help students see those connections.

Opportunities and Challenges

In this focus area, participants took a more integrated approach to discussing opportunities and challenges, citing their difficulty with authentically separating them and treating them distinctly. Overall, a core challenge to achieving their vision of progress involves entrenched perceptions of the role of the mathematical sciences within higher education. Mathematical sciences coursework, particularly in the first 2 years, has long been viewed by faculty as a gatekeeper used to weed out students deemed unprepared for STEM programs. Although this culture has been changing in recent years, these changes are still too isolated or episodic to have led to large-scale impacts. Intentional structures must be built and sustained to support meaningful collaboration focused on improving student success.

Another challenging aspect of the mathematical sciences culture in higher education is the elevation of calculus as the gold standard of mathematics courses. More institutions are now offering additional mathematics pathways, and participants endorsed this progress. However, along with offering multiple pathways, faculty and advisors need to better communicate the value that each pathway offers. Additionally, curricula across all pathways, including calculus, need to demonstrate the relevance of mathematics (e.g., career options, social and environmental issues, public health, personal decision-making).

Other higher education structures pose barriers as well. For example, large lecture course formats are particularly problematic for student-centered pedagogies and tend to utilize inequitable assessment practices. In cases where large lecture classes are unavoidable, faculty need training and support to integrate practices that help build relationships and engage students in active learning.

Across all aspects of teaching and learning, participants identified deep and sustained professional learning as critical for progress. There is a particular need to focus on active learning, equitable instructional practices, and culturally responsive and sustaining pedagogy. Participants pointed to sustained opportunities for partnerships and collaboration across the K–12 and higher education sectors and across disciplines within higher education as an opportunity to offer training and build a community around teaching and learning.

Leveraging the department as the unit of change rather than the individual is also a promising strategy cited for sustaining change in practice and culture. For example, the practice of assigning the least-experienced and least-supported faculty, instructors, and teaching assistants to entry-level courses is both a challenge and an opportunity. On one hand, it means that instructors who have not had time to improve their instructional practices are teaching the students with the greatest need for support. Teaching assistants and early-career tenure-track faculty can be under a great deal of pressure to prioritize their own programs and research, and adjuncts, because they are often poorly paid, have to divide their time between multiple jobs. On the other hand, these faculty and instructors often do not share the deeply entrenched attitudes about teaching that can be problematic in some senior faculty, and they are often more open to innovative teaching practices if they are supported in their own learning and given the time to focus on instructional improvement.

The ways in which mathematics understanding and competence are typically assessed poses another challenge to providing students with equitable access and opportunities to learn. Standardized placement testing has been shown to be ineffective and inequitable. Additionally, classroom assessments that prioritize algorithmic procedures over conceptual understanding further separate assessment results from mathematical understanding. Faculty and instructors need time and resources to identify and use equitable, mathematically rigorous assessments that are practical within their time constraints.

There are also barriers to equitable participation and opportunities that go beyond the classroom. The institutions that serve the largest number of minoritized students are less resourced and have the fewest opportunities for grants that support research and innovation. Predominantly white and highly selective institutions have a great deal of work to do to create environments that welcome and support students who are currently minoritized by race and income. There is also a general need for more research to identify practices that will result in equitable outcomes and experiences that will aid in implementing these practices at scale.

Finally, participants identified technology as an opportunity for improving undergraduate mathematics, particularly with respect to adaptive learning and data-driven instruction. Potential applications of AI—and the need to ensure equitable access to advances in AI—are considered vital areas for exploration. However, discussion on this topic was limited, not because participants did not think it was important, but because the emerging nature of this technology still makes it challenging to envision what is possible.

Recommendations for Research, Policy, and Practice

This section includes participants' recommendations for research, policy, and practice. Additional recommendations for funding organizations can be found at the end of this report in the section "Recommendations for Funding Organizations."

Undergraduate Mathematics Teaching and Learning: Research Recommendations

Participants' recommendations for research on improving undergraduate mathematics teaching and learning (UM-R) span a series of themes, including assessment, scaled implementation, technology, elevating the role and value of effective teaching in higher education, inclusive research, and systemic change.

UM-R 1: Study the impact of culturally relevant learning metrics and formative assessment that support active, experiential learning. Research on reimagining assessment and student learning metrics can help faculty, departments, and institutions move beyond traditional assessment structures, promote an interconnected focus on mathematical content and practices (e.g., ability to construct and critique mathematical arguments, ability to proficiently engage in problem solving and research activities), and understand the impact of assessment on students' mathematical identity and other outcomes. Assessments should leverage adaptive learning technologies and reflect value for a broad range of academic and career progressions that require practical applications of mathematical learning, interdisciplinary collaborations, and continued development of the discipline through basic research.

UM-R 2: Examine how effective pedagogical practices and professional learning models are scaled and sustained in equitable ways. There are many examples of faculty and departments that are using evidence-informed pedagogical practices effectively. However, more research is needed to understand how to scale these practices and the professional learning that supports them beyond these contexts. This is particularly challenging given differences between institutions, resources, and the students they serve. Proven strategies for ensuring that faculty at all institutions have access to the support needed to adapt these practices for their students and monitor their impact are important to ensuring equitable access to high-quality instruction.

UM-R 3: Study ways in which AI and other technologies can be responsibly, ethically, and equitably used to improve student outcomes. New developments in AI, information technology, adaptive learning models, and modeling tools offer potentially valuable tools to support students' mathematical learning and experiences. Research on the use of these technologies is critical to understanding the opportunities and potential for harm, especially in regard to supporting diverse learning needs.

UM-R 4: Explore strategies for elevating teaching in higher education. Competing priorities impact how faculty invest their time and resources. This creates a need for departments and institutions to identify, enact, and study strategies to elevate teaching. Examples include

- examining how departments and institutions support effective teaching for all faculty, including collecting and disseminating evidence of the impacts of institutional systems and structures that value and reward high-quality instruction;
- establishing and supporting practical dissemination of strategies and teaching methods that support students' transitions from K–12 to postsecondary mathematics education, lead to positive impacts on students from underserved communities, and result in higher outcomes overall that are consistent across subpopulations; and
- identifying metrics for evaluation of teaching that extend beyond end-of-course evaluations to include outcomes that are relevant for specific institutional and student characteristics (e.g., student progression, degree completion, career development).

UM-R 5: Promote inclusive approaches to all research activities to ensure participation and representation from different institution types. Partnerships between different types of institutions can help increase the capacity of institutions that serve important student populations but may not have the resources to conduct research. For example, participants recommended that faculty at research institutions partner with faculty at 2-year institutions or Tribal Colleges and Universities (TCUs) where faculty have high teaching loads and may not have the time, resources, or administrative capacity to conduct a study on their own. This is critical to ensuring that the student populations served by these institutions are included in research on teaching and learning.

UM-R 6: Investigate critical questions related to systemic cultural and structural changes. Many of the recommendations for improving higher education require systemic cultural and structural changes. Enacting this type of change is challenging and requires coordinated efforts to address some critical questions. Examples of such questions include the following:

- What drives or hinders sustainable change?
- What theories and systems of change are effective for changing culture and teaching practice in mathematics departments?
- What standards of evidence would convince various audiences of the need for change?

Undergraduate Mathematics Teaching and Learning: Policy Recommendations

Several recommendations highlighted the important role policies at the departmental and institutional levels and broader legislation play in improving undergraduate mathematics teaching and learning (UM-Pol). These focused on pedagogy and instruction, postsecondary mathematics pathways, technology, and several issues related to teaching in higher education.

UM-Pol 1: Incentivize and reward evidence-based, equity-focused instruction. Institutions and departments should create policies and structures that support and sustain equity-focused pedagogical shifts. These policies should include parallel incentive and reward mechanisms to those currently in place for other professional activities (e.g., research). They should also identify and utilize evidence-based metrics that extend beyond end-of-course evaluations (e.g., demographic breakdowns of student outcomes); focus on inclusive, equitable outcomes; and reflect the unique culture and context of institutions and the students they serve.

UM-Pol 2: Establish and support mathematics pathways that support opportunities for a broad range of career pathways and advanced studies. Well-aligned pathways across secondary and postsecondary education are essential to providing students with a broad range of options. States, systems, institutions, and departments should provide the resources needed to eliminate developmental education and support immediate enrollment in high-quality gateway courses that earn college credit and meet general education requirements with corequisite support. States and systems should support work across institutions and sectors to build aligned mathematics pathways that provide students with clear academic and career pathways. The impact of these pathways on equitable access and outcomes should be assessed and monitored.

UM-Pol 3: Ensure equitable access to technology that supports mathematical learning for all students. It is essential for policymakers, states, and institutions to invest in the infrastructures needed to keep up with technological innovation, including resources and professional development for faculty and student access to the devices and connectivity needed to consistently leverage technology to support their learning. It is also essential that this is done in a way that ensures all students at all institutions have access to these resources and technology.

UM-Pol 4: Elevate the teaching profession for mathematics faculty. Policymakers, states, institutions, and departments should examine whether current incentives and rewards are tied to the time, resources, and scholarship faculty devote to improving their instructional practice. In cases where they are not, policies, structures, practices, and cultures should be revised in ways that place greater value on achieving equitable student outcomes, including affective components linked to student progression, degree completion, and career development (e.g., motivation, mathematical identity, sense of belonging). This can include policies related to evaluation, promotion, compensation, and pedagogical training requirements. Alignment and collective efforts from officials and administrators at all levels to elevate teaching are essential for sustained systemic change.

UM-Pol-5: Create graduate degrees or certificates focused on teaching undergraduate mathematics, particularly for those teaching in the first 2 years. Providing formal training in undergraduate mathematics teaching can be a first step in a long-term progression toward requiring mathematics faculty who teach particular courses or work with particular student populations to have a teaching certificate or credential focused on teaching introductory mathematics courses. Similar courses for teaching more advanced mathematics and training future researchers could also be beneficial.

Undergraduate Mathematics Teaching and Learning: Practice Recommendations

Participants' recommendations for practice (UM-Prac) focused on pedagogy and instruction, professional learning, postsecondary mathematics pathways, technology, assessment, and the role of departments in driving progress in this area.

UM-Prac 1: Support all faculty in implementing equitable instructional practices to develop students' sense of belonging, positive mathematical identities, and problem solving skills. Equitable instructional practices include active and collaborative learning, culturally responsive and sustaining strategies, and expanded approaches to assessing student learning of mathematical content and practices. These practices require resources and scaffolded supports for faculty with varying levels of experience and commitment to equity-focused practices.

UM-Prac 2: Regularly engage faculty in professional learning that supports pedagogical development and builds connections across disciplines and educational sectors. Institutions and departments should ensure faculty have the time, resources, and incentives needed to regularly engage in professional learning. This can encompass a variety of activities including workshops, observations, shared practices, and joint development projects. Professional learning should be practice oriented and collaborative in nature. It should also extend beyond the department and institution to promote cross-disciplinary and cross-sector engagement (e.g., K–12, community colleges, universities) that supports and sustains learning through a network or community.

UM-Prac 3: Provide students with multiple entry points for learning and excelling in the mathematical sciences and multiple options aligned to a range of academic and career goals. To ensure students have access to multiple options and opportunities, developmental education should be replaced with evidence-based corequisite models for students who will benefit from extra support to increase success in gateway mathematics courses and accelerate progress toward completion. The process and resources required to implement this will vary by institution. Departments should not be expected to make this transition without designated resources and explicit support in determining the appropriate mechanisms for such a transition within the contexts of individual institutions.

UM-Prac 4: Create opportunities for faculty to learn about existing and emerging technologies that can enhance instructional practice and student experiences. Institutions and departments should provide faculty with the resources needed to learn about current and emerging technology and integrate it into their practice. Access to such resources can come through departmental or institutional professional development or dedicated time and funding to participate in conferences, webinars, and other external professional development.

UM-Prac 5: Establish expectations and incentives to actively identify and eliminate barriers to student success. Departments should be expected to build a culture and structures that leverage the unique strengths of all faculty to support students through sustained improvement efforts. Incentives and support for identifying and eliminating barriers to student success offered by institutions, professional societies, and other industry and government organizations can help prioritize this work.

Meaningful K–12 Career Pathways

Discussions on building meaningful K–12 career pathways first focused on describing the mathematical learning experiences students need to ensure they have a range of career options and are not inadvertently locked out of particular jobs in the future. Participants also discussed the meaning of the term *pathway* to find a common definition. There was some consensus that, for the purpose of these discussions, the term *pathway* would represent different professional avenues and should not be confused with controversial tracking structures and practices that can limit students' access to advanced mathematics. Participants agreed that K–12 career pathways should include multiple entry points and ongoing opportunities for students to easily move between options without issue or detriment.

Several participants expressed concerns that an overemphasis on career alignment in mathematics education risks limiting the purpose of mathematics education to serving industry and society rather than providing all students with opportunities for meaningful engagement with mathematics in the world around them. All students should have the opportunity to build the knowledge and skills needed to prepare them for current and future careers without this becoming the sole purpose of their mathematics education. Participants advocated for a

balanced focus on career preparation and mathematical learning that fosters personal development of numeracy skills, logic, reasoning, problem solving, curiosity, and creativity.

Vision for Progress

Throughout the convening, participants identified several core elements of an equity-focused approach to building meaningful K–12 career pathways that draw on mathematical learning. These include

- shifting teacher mindsets to view all postsecondary progressions as viable options for all students, including higher education and direct entry into a variety of professions;
- expanding exposure and access to a range of career options, particularly for students from underserved communities who may not be aware of the opportunities available to them;
- creating channels for students to build their professional identities by connecting with professionals with similar racial, ethnic, and cultural backgrounds or from similar communities;
- providing equitable access to resources that support informed and empowered decision-making; and
- expanding students' access to authentic, context-based learning experiences.

There was wide agreement that students should be able to **connect mathematical concepts, skills, and practices to authentic contexts** throughout their K–12 mathematics experience. Authentic contexts should reflect topics and issues that reside in or are relevant to students' communities, prepare them for a broad range of professional pursuits, and provide them with opportunities to engage with mathematics in ways that are personally meaningful and fulfilling. All community contexts have authentic problems that provide opportunities for mathematical learning and development. Connecting students to these problems and the people using mathematics to address them can help students see mathematics as personal, powerful, and consequential. It can also empower students to see themselves as capable of contributing to future solutions and progress. This way of experiencing mathematics is synergistic in that students learn mathematics, build mathematical identity, engage in meaningful activities, and develop agency as community-based problem solvers.

Participants' vision for increased exposure to different types of careers was characterized by **curricular progressions with multiple entry points** and opportunities to move between associated pathways. This is particularly important for middle and early high school students as they consider implications for course selection. Resources for teachers to support these explorations can be embedded in the mathematics curriculum, provided by partners or guest speakers, or included in career-based professional learning communities. Transparent systems are also necessary to inform students about the mathematics requirements associated with

various career paths. These rely on training, resources, and collaborative structures for counselors, administrators, teachers, parents, and industry partners to support student decision-making related to postsecondary options.

Progress in this area also focused on reimagining the **K–12 curriculum and K–12 instruction** to incorporate flexible, relevant mathematics course options at different stages in students' mathematics education. These courses should include authentic, real-world problem solving experiences and contexts aligned with different industries and career interests, including local businesses and community organizations. Support for these shifts could be provided through peer-to-peer learning, near-peer mentoring, and a repository of engaging mathematics labs and experiments for all levels.

Participants articulated that mechanisms and incentives for **collaboration across sectors and education levels** are essential for this type of progress. These should include structured opportunities for collaboration among K–12 teachers, postsecondary mathematics educators, and industry leaders. Such collaborations could also support evaluation measures for K–12 districts that include longer-term college and career outcomes.

Finally, participants believed that increased opportunities for students to **engage with their local communities** will connect students to community problems and progress initiatives involving mathematics, fostering a sense of contribution and meaning. This envisioned community engagement relies on broader collaborations between local industry and business professionals, community organizations, and educational programs to create or identify relevant opportunities for students.

Opportunities and Challenges

Participants discussed several current features and contemporary trends in education, society, and innovation that provide both opportunities and challenges for building meaningful, inclusive K–12 pathways for a range of postsecondary options, including direct pathways into careers that draw on mathematical knowledge and skills. The opportunities include

- a growing number of investments, programs, and policies that support engagement and collaboration between K–12 schools, career training programs, and STEM industry partners;
- an increasing focus on building and leveraging an academic-professional infrastructure of certifications (i.e., certifications for employment that does not require a college degree); and
- commitments from industry programs and professionals to support and contribute to development of mathematics curricula and programs for students and teachers.

There is strong interest among government, industry, and funding organizations in supporting research and development related to integration of new technology, AI, and coding into

education, as these skills are likely to become increasingly important to the workforce. Participants discussed the importance of leveraging such interest in partnerships and collaboration to establish repositories for mathematics labs, expanding approaches to assessment and accountability measures (i.e., expanding beyond summative or end-of-course exams), and promoting diverse career exploration events for students.

The panelists noted that one of the biggest barriers to equity is the lack of integration between mathematics coursework and career pathways. They also raised concerns about the potential channeling of students based on the priorities of a particular type of pathway. They noted that students of color are often encouraged to pursue particular pathways that might restrict their future options, reflecting inequitable distributions of resources. An illustrative example was shared about how exposure to a research laboratory in an isolated community expanded students' perceptions of possibilities and capabilities. Participants also noted that students from marginalized communities may face barriers in advancing to higher-level mathematics classes beyond their control (e.g., course offerings, teacher availability), limiting their preparation for many postsecondary options.

Challenges that have created barriers to progress or may hinder future progress include

- limited resources in schools—adding curricular content, structures, and experiences requires teachers with specific training and resources, which may not be feasible for many schools;
- the rapidly changing nature of technology and its influence on industry and society;
- lack of awareness among guidance counselors about diverse career pathways;
- a historic lack of influence from industry on curriculum design; and
- career pathways without multiple entry points, flexibility, and mobility, which can narrow or restrict students' postsecondary opportunities.

Furthermore, participants questioned the extent to which K–12 students are actually motivated by connections to future careers, particularly in middle and early high school. Participants were not convinced that highlighting connections to specific careers has any impact on motivation, engagement, and constructs such as mathematics identity. They felt that more research is needed to truly understand the validity of this hypothesis.

Recommendations for Research, Policy, and Practice

This section includes participants' recommendations for research, policy, and practice. Additional recommendations for funding organizations can be found at the end of this report in the section "Recommendations for Funding Organizations."

K–12 Career Pathways: Research Recommendations

The following research recommendations (CP-R) focus on research that can offer valuable insights for enhancing K–12 mathematics education, promoting diverse career pathways, and supporting students' academic and career success.

CP-R 1: Investigate issues that impact equitable access to mathematics pathways and postsecondary opportunities for underserved student populations. Research should examine strategies that ensure equitable access to mathematics education, exposure to diverse careers, and resources that enable students with racial, ethnic, and gender identities, cultures, and backgrounds that are underrepresented in STEM to pursue mathematics-related career pathways. This research should focus on building evidence-based practices for dismantling barriers for school systems and teachers working to provide more equitable mathematics pathways and postsecondary opportunities for all students.

CP-R 2: Examine how differential high school graduation requirements and course offerings impact students. Research is needed to determine the ways in which variations in graduation requirements and access to course offerings affect access to mathematics-intensive career pathways, particularly for students from minoritized and lower socioeconomic backgrounds.

CP-R 3: Identify and understand the factors that influence postsecondary progressions. Research partnerships across sectors and education levels should investigate the factors that impact students' postsecondary choices (e.g., career choices, postsecondary studies). These factors can help to ensure all students feel that it is possible for them to pursue postsecondary options that utilize and build on their mathematical learning.

CP-R 4: Build an evidence base for effective strategies for developing and measuring the mathematical skills and practices needed for all careers. In addition to content-focused professional learning, teachers need mathematics-specific professional learning that provides ongoing support with evidence-based strategies that improve student outcomes related to the mathematical thinking, reasoning, skills, and experimentation required in all careers. Research is needed to both establish these strategies and determine ways of measuring the desired mathematical skills and practices.

CP-R 5: Examine the extent to which connecting mathematical learning to future careers can positively impact students' perceptions of mathematics, mathematical identities, engagement, learning, and achievement. There is uncertainty regarding the extent to which connecting mathematics to a range of careers can positively impact affective and cognitive outcomes in mathematics, particularly for students in elementary and early secondary grades. Research should focus on clarifying if and how these connections are valuable.

CP-R 6: Study the effectiveness of strategies and programs designed to connect students to career pathways that utilize mathematical skills, knowledge, thinking, and reasoning. This should include an examination of factors that influence teachers' adoption of career-aligned curricula, content, and practices in their classrooms; efforts to establish appropriate effectiveness metrics; and a shared understanding of what effectiveness means for such strategies and programs. Examples include

- programs that bridge K–12 mathematics education and career pathways, with a focus on exposure to diverse careers, and
- mentorship programs, industry partnerships, and career counseling focused on students' decisions to pursue mathematics-intensive careers.

CP-R 7: Examine the implementation and impact of K–12 mathematics course content, selection, and progressions on postsecondary options. Evidence is needed on effective ways to structure course content, selection, and progressions (e.g., data science vs. calculus pathways) and the ways in which these impact students' postsecondary options. Examples include

- conducting longitudinal studies to assess how K–12 mathematics education influences students' postsecondary choices, especially in relation to STEM fields, including an examination of differences across demographics;
- evaluating the effectiveness of different mathematics curriculum models in preparing students for postsecondary mathematics requirements and careers;
- conducting quantitative and qualitative research on successful collaborations between high schools and 2-year higher education institutions to prepare students for vocational careers, emphasizing mathematical and technical skills; and
- studying the necessary conditions and best practices for implementing partnership programs that facilitate seamless transitions from high school to vocational education.

CP-R 8: Assess the feasibility and impact of integrating computing into the K–12 mathematics curriculum. Some areas of need for research on the integration of computing into K–12 curricula and instruction include the following:

- Identify and study potential models and determine the structures and resources needed to equitably integrate computing into the K–12 mathematics curriculum across all schools. Studies should include research questions related to options for ensuring that students have access to teachers with the competencies needed to teach computing, such as these:
  - Is it reasonable to place this expectation on mathematics teachers, and if so, what are the implications for such an expectation on equitable access?

  - Are there effective coteaching models for interdisciplinary teaching or a resident technology innovation specialist who works with mathematics or other STEM teachers?
- Study whether integration of computing skills into K–12 mathematics education has a positive impact on students' readiness for STEM careers.
- Examine ways in which including computational thinking in mathematics curricula may impact students' problem solving skills and interest in mathematics-related fields.

CP-R 9: Critically examine the role of incentives and supports for encouraging districts and schools to authentically integrate STEM into their curricula, instruction, and assessment systems. While incentives can be an important and effective mechanism for driving change, particularly as a positive alternative to deficit-oriented accountability structures, they must come with strategies and provisions that ensure equitable opportunity and access for all schools and districts, particularly those with fewer resources.

K–12 Career Pathways: Policy Recommendations

The following recommendations aim to improve the development and enactment of policy related to K–12 career pathways that involve mathematical learning (CP-Pol). They address incorporating STEM curricula, aligning mathematics pathways with career options, updating content standards, expanding evaluation measures, and fostering teacher competencies in data science and computer programming.

CP-Pol 1: Promote collaboration over competition. Policies, grants, and awards can serve to incentivize and reward innovation, progress, and achievements related to STEM content, curricula, and achievement. However, competitive approaches to accessing new programs or funding can primarily end up further benefiting those schools with the resources to pursue and implement these opportunities. To address this, programs can require schools, districts, and community organizations with the resources to prepare grant proposals or implement innovative initiatives to partner with those who do not have these resources.

CP-Pol 2: Elevate connections between K–12 mathematics coursework and career pathways in standards and policy documents. To help ensure that all students have the opportunity to learn mathematical content, develop mathematical practices, and have mathematics experiences that support a range of career options, standards and policy documents should include alignment of course content with the type of professional activities it supports. This can support districts, schools, and teachers in making these connections for students and determining course offerings.

CP-Pol 3: Require middle and high schools to explicitly and transparently align their course offerings and course progressions with college and career options. Students and families need better information and resources to help them advocate for access to courses and make informed decisions about enrollment. This is particularly important for ensuring that all students have the opportunity to pursue postsecondary options in STEM fields.

CP-Pol 4: Update K–12 mathematics curricula and standards to keep pace with modern industry needs. Strategies for ensuring that mathematical content remains current and relevant include the following:

- Establish a mechanism for local, state, and federal agencies and leaders across sectors to provide guidance on and support for adjustments to mathematical content and curricula aligned with contemporary developments in industry, technology, and society.
- Encourage professional organizations and policymakers that shape curricular content, standards, assessments, and teacher preparation to regularly revise relevant documents or legislation to reflect the modern needs of industries such as data science, technology, engineering, and finance. These groups should also provide guidance to practitioners and leaders across all levels of education related to implementation of any such updates.
- Ensure that mathematics curriculum and assessments incorporate relevant skills and knowledge necessary for students to succeed in current and emerging career fields.

CP-Pol 5: Expand K–12 outcome and achievement metrics to include student success in college and careers. In addition to metrics such as graduation rates or standardized test scores, metrics for school success should include longitudinal measures of students' preparedness for the degrees or careers they choose to pursue. This should be implemented in ways that prioritize formative feedback for continued development. For example,

- advocate for measures that can evaluate and generate feedback for high schools based on their students' success in college and careers, including their proficiency in the mathematical knowledge and skills required by their postsecondary education and/or career pathways, and
- establish monitoring systems that track students' progress from K–12 education to higher education and/or into the workforce to determine the extent to which they developed the knowledge and skills needed to pursue a range of postsecondary options—this includes mathematical practices and other transferable skills.

CP-Pol 6: Provide and support flexible, varied models for teacher preparation, hiring, and professional development to ensure students have access to teachers with competencies in data science and computer programming. Flexibility in teacher education and staffing is essential to ensuring that practices can be adapted to provide students access to valuable content across different school and community contexts. For example,

- provide training and professional development opportunities for educators to enhance their data science and computer programming competencies, especially in the context of mathematics education, and
- encourage teacher certification programs to include coursework related to data science and computer programming to better prepare educators for teaching mathematics in a changing technological landscape.

K–12 Career Pathways: Practice Recommendations

The two practice recommendations for K–12 career pathways (CP-Prac) focus on creating student learning experiences that explore career opportunities and cross-sector partnerships that ensure these learning experiences are sustained. While not specifically included in this section, implementation of many of the evidence-based strategies referenced in the research recommendations would also be relevant for practice in this area.

CP-Prac 1: Develop and implement curricula and professional learning that promote experiential, career-aligned learning opportunities. These can include new content as well as reorganization of existing content or standards in ways that promote opportunities for integrated, thematic, or experiential learning (e.g., problem-based and project-based learning).

- Schools should prioritize incorporating experiential learning into mathematics education and providing students with hands-on activities and real-world applications of mathematical concepts through labs, project work, cross-disciplinary courses, and other innovative mechanisms. Ensuring that this is feasible for all schools will require collective efforts from a range of interested parties to create policies, funding opportunities, structures, and incentives for well-resourced schools, districts, local institutes of higher education, and others to partner with less-resourced schools to provide access to these learning opportunities (e.g., virtual math labs that include students from multiple schools).
- Cross-sector collaborations should draw on a range of expertise to offer just-in-time teacher training to equip educators with the skills and knowledge needed to provide mathematics instruction that supports contemporary career pathways. Creative approaches to providing this training are critical to reducing barriers for teachers to access this training (e.g., limited time and resources).
- Cross-sector partners (e.g., industry, government, nonprofits, community, professional societies) should work together to develop a repository of math labs and experiments

linked to authentic problems that provide teachers with resources to engage students in meaningful mathematical experiences.

CP-Prac 2: Build, share, and support new models for partnerships between mathematics educators and government, industry, and nonprofit professionals. This recommendation is important for superintendents, industry executives, government officials, and others who are in a position to drive and support such initiatives within their district or organization. These partnerships can focus on

- creating micro-experiences for students, giving them insight into the practical applications of mathematics in various career pathways;
- establishing structured processes for organizing engaging and relevant career days that showcase diverse professionals and career opportunities related to mathematics; and
- providing teachers with funding for site visits, allowing them to gain insights into current industry practices and better connect mathematics education with career pathways.

Crosscutting Themes

Throughout the convening, across all focus areas, participants articulated a systemic need to reconceptualize many aspects of mathematics teaching and learning to **create more inclusive, equity-focused approaches to mathematics education**. Many of these discussions focused on representation within the mathematical sciences, including those who teach at all levels. These aspects ranged from preparation of mathematics educators to course structures and offerings to the methods and metrics that measure success and desired outcomes. Approaches to these and many other aspects of mathematics education must be critically examined to reduce bias, increase inclusivity, and ensure opportunities to demonstrate progress and measure success that integrate the unique cultures and contexts of our institutions and the students they serve.

Participants also **cautioned against over-alignment of the content and purpose of mathematics education with STEM careers, industry, and technology.** There was widespread agreement on the need for school–industry partnerships to ensure that all levels of mathematics curricula and instruction (early childhood through graduate) prepare students for modern careers and society. However, participants also expressed concerns that overemphasis on career-related applications and utility can limit students' opportunities to explore and appreciate mathematics as a rich, meaningful part of their own lives. For all students to see themselves as learners and doers of mathematics, mathematics education must be considered a valuable part of their human development and as a tool that empowers their creativity and ability to understand and engage with the world around them.

In all aspects of the convening, participants continually noted a **tension between the need for new ideas and the need to effectively scale and adapt successful, small-scale work** with a

demonstrated impact in specific contexts. Participants shared countless examples of effective programs and initiatives developed with grant funding that have not had the resources to continue beyond their funding period. As a result, there are many examples of what effective practice entails in specific contexts with specific populations, but participants often referenced a lack of consensus on what constitutes effective practices or equity-focused pedagogy. Participants recommended a centralized way to access details and research on these initiatives and investment in projects and partnerships, with a substantial focus on practical dissemination strategies that explicitly aim to transform research findings into practice and policy (e.g., videos that demonstrate translation into practice; one-pagers or sample legislative text that translate findings into recommendations for state, district, or federal policymakers).

These efforts require **partnerships in which researchers, practitioners, and policymakers collaboratively translate research findings into programs, structures, policies, and practices** that are iteratively enacted, studied, and revised. Such partnerships can build consensus about evidence-based practices that should be widely adopted and show how evidence-based recommendations can be effectively and equitably implemented across contexts. While connecting research, policy, and practice is not a new concept, investments in the partnerships and structures needed to support them is an area that still needs further development. Participants also noted the uniquely appropriate time for such a focus, given that the pending expiration of COVID-19 funding in educational settings presents an opportunity to learn from how programs established with these funds are sustained or lost when the funding ends.

Discussions of partnerships further spanned the focus areas in their exploration of strategic approaches to **fostering mutually beneficial engagement between K–12 teachers, higher education faculty, and researchers** across the mathematical sciences and mathematics education. Short-term exchanges and long-term residencies were examples of the type of structures discussed. However, more informal opportunities for facilitated conversations between faculty at different institutions or schools in different communities were also considered beneficial. This was articulated in post-convening survey responses that described the shifts in perspectives and new ideas that emerged from the opportunity to spend time with people with different backgrounds who engage with mathematics in different ways. This idea was further reinforced by participants in the virtual working groups that reviewed recommendations following the convening. For instance, several participants working in higher education reflected on how much they learned from discussing issues with others in very different types of institutions (e.g., 2-year institutions, research institutions, TCUs).

In addition to learning from each other, **partnerships were seen as a key mechanism to improve equitable access to resources and funding opportunities**. For instance, funding proposal requirements alone can be a barrier for some schools, institutions, and organizations. They do not have the staff, resources, and structures that others have to support development and submission of a competitive funding proposal. Additionally, schools and institutions serving the student populations that should be central in educational research often do not have the

resources, time, or expertise to conduct research. In both cases, partnerships between well-resourced organizations or research institutions could reduce barriers to accessing funding.

Another crucial theme across focus areas was **keeping students at the center of all aspects of progress**. During the convening, this initially emerged from the student panel that featured in the opening activities. The students on this panel reminded participants that some of their most effective teachers and professors stood out for their interactions with students more than for their teaching of the content. At all levels, participants agreed that instructional improvement should focus on both content-oriented instruction and relational practices that build community, trust, and a sense of belonging. Additionally, across all focus areas, participants noted that improvement efforts should move beyond seeing students as recipients of these efforts to engaging them as valuable partners in identifying, designing, and evaluating the effectiveness of new strategies and practices meant to drive progress.

Finally, participants consistently sought to identify ways to **elevate teaching and the teaching profession** across all levels of mathematics education. While some of these discussions were about teaching in general, many were specific to mathematics. For instance, teachers with strong mathematical backgrounds typically have many higher paying career options with opportunities for advancement. More needs to be done to ensure that teaching can compete with these careers. In higher education, the mathematical sciences provide critical knowledge and skills for STEM and other disciplines. Academic cultures that value and reward high-quality teaching, particularly in the first 2 years of undergraduate mathematics and statistics, are more likely to see student success in the mathematical sciences and other related disciplines.

Recommendations for Funding Organizations

In addition to the recommendations for research, policy, and practice for each focus area, convening participants identified a series of recommendations for other funding organizations. Many of these recommendations echo those of previous sections of this report and focus on improving equitable access to funding opportunities and the impact of funding on equitable outcomes for students. They prioritize ways to support collaborative efforts to improve mathematics education at scale across the entire K–12 and postsecondary education system. They also advocate for investments in translating research into practice.

While some recommendations are discussed within the context of specific focus areas, there was consistency in the recommendations that emerged across all areas. For example, all areas include recommendations for supporting partnerships and reducing barriers for new principal investigators (PIs) and organizations. In addition to recommendations for each focus area, this section concludes with a list of additional crosscutting recommendations.

K–12 Mathematics Teachers Preparation

FND-TP 1: Require at least one teacher or instructional leader to be a PI, co-PI, or advisory board member for relevant funding programs. To facilitate this, funding organizations should provide an abbreviated practitioner guide as a supplement to the *Proposal and Award Policies and Procedures Guide (PAPPG)* to help those who do not have proposal preparation resources to navigate the required documents. Funders should also ensure that biographical sketch templates highlight the professional experiences of practitioners with practice-oriented achievements that extend beyond publications.

FND-TP 2: Include teachers and other K–12 practitioners and leaders on review panels. To help manage power dynamics, initial invitations and other guidance from program directors should empower teachers and other K–12 practitioners to share their unique perspectives and elevate practice-focused insight during panel discussions.

FND-TP 3: Include language in programs and solicitations that discourages the use of deficit language in reference to students and teachers. When assigning reviewers to relevant proposals, encourage them to flag incidents of deficit language in their reviews as opportunities for feedback for project teams.

FND-TP 4: Expand support for programs that foster collaboration among K–12 teachers, higher education faculty, and industry or government organizations. Programs such as Research Experiences for Teachers could be expanded to include programs that provide industry experiences for teachers. Programs that encourage coteaching experiences between K–12 teachers and higher education faculty should also be considered, particularly those in which faculty and industry or government professionals work with teachers to engage students with problems that develop valuable mathematical skills and practices (e.g., problem solving, research activities, proof, collaboration, communication).

FND-TP 5: Support development of evidence-based facilitation tools and strategies for interactions among mathematical sciences researchers, teacher educators, and K–12 teachers. Intentionally designed, evidence-based facilitation strategies are important for productive engagement among those involved in mathematical sciences research and all levels of education. These tools and strategies are needed to manage power dynamics and ensure all participants feel empowered to share their specialized knowledge, ideas, and perspectives.

FND-TP 6: Provide funding, structures, or resources to enhance mechanisms for sharing and disseminating mathematics education tools and initiatives. This can be accomplished through initiatives such as creating centralized repositories, leveraging social media, and coordinating with professional societies and partner organizations.

Undergraduate Mathematics Teaching and Learning

FND-UM 1: Identify and reduce barriers for under-resourced institutions to compete for and manage funding. Ensuring access to resources for improving undergraduate mathematics teaching and learning is particularly important for institutions that serve underrepresented populations, such as 2-year colleges, TCUs, Historically Black Colleges and Universities (HBCUs), Hispanic Serving Institutions (HSIs), and other Minority Serving Institutions (MSIs). Strategic partnerships can be a mechanism for sharing resources and ensuring inclusion of important student groups in research on undergraduate teaching and learning.

FND-UM 2: Encourage use of metrics for student success that extend beyond course grades and traditional assessments. Explicit solicitation language or funding programs that expand the ways in which researchers, administrators, policymakers, and other leaders define and measure student success are critical to ensuring that these metrics align with the unique characteristics of diverse student populations across institutions, departments, and communities.

FND-UM 3: Promote inclusion of community-based organizations in projects. Members of community-based organizations are often better positioned to represent the cultures, values, and experiences of the students in their communities than academic faculty or researchers in other organizations. Programs and solicitations can encourage involvement from more community-based organizations by expanding eligibility criteria, creating more flexibility regarding expertise in required documents or content (e.g., biosketch, prior funding), naming them in language regarding partnerships, and ensuring representation on review panels.

FND-UM 4: Expand support for projects and partnerships that translate research into practice. Promote mechanisms for ensuring faculty and others who teach courses in the mathematical sciences, particularly in the first 2 years, have access to research on teaching and learning and support for translating this research into effective instructional practices. Avenues for access should be diverse, including open access, practice-oriented outlets, graduate and postdoctoral teaching assistant training, and structured professional learning opportunities (e.g., professional learning communities). Additionally, replication studies should attend to scaling and studying successful models in a range of different contexts (e.g., institution types, department sizes, learning modalities, students served).

Meaningful K–12 Career Pathways

FND-CP 1: Develop programs and solicitations that provide strong incentives for collaboration among education, industry, community, and policy partners. Partnership opportunities can range from large grants that support new research or professional learning partnerships to micro-experiences for students that offer insight into practical applications of mathematics in various pathways to flow-through grants that facilitate industry visits and connections for teachers and students. Representatives from these communities should be invited to support

new development or adaptation of programs and solicitations. Such activities could also be explicitly encouraged as part of the broader impacts for projects within a particular program.

FND-CP 2: Ensure that proposal requirements provide opportunities to highlight the unique professional experiences of industry, government, and policy partners. To encourage strategic partnerships, required proposal content and documents (e.g., biosketch, prior funding) need to provide opportunities to highlight activities and achievements that extend beyond research and publication.

FND-CP 3: Improve and expand communication channels to broadly disseminate the results of collaborations among education, industry, community, and policy partners. Encourage creative approaches to dissemination and provide appropriate support to ensure that all members of cross-sector partnerships can engage in relevant dissemination activities within their different communities.

FND-CP 4: Create programs that focus on implementing evidence-based career pathway initiatives and establishing appropriate measures of effectiveness. Many successful career pathway initiatives require time and resources that create barriers to implementation. Research on scaling initiatives and measuring their effectiveness in ways that attend to diversity in race, ethnicity, gender identity, geography, and socioeconomic status, as well as access for students with disabilities, is essential to overcoming these barriers.

FND-CP 5: Support organizations or institutions without prior grant funding as they pursue new partnerships and collaborations. Resources to promote engagement from new partners may include matchmaking with experienced grantees and incentives for experienced grantees to work with new partners.

Additional Recommendations

FND-AR 1: Explicitly require funding proposals to specify how their work will interrogate and dismantle inequities. Relevant programs should explicitly require proposals to address inequity (racism, classism, ableism) in mathematics education; describe how their work includes an equity-focused innovation; and address how the proposed work will benefit those who are most marginalized in mathematics education. Proposals should receive added priority for proposed innovations that meet the needs of multiple populations. This draws on evidence that focusing on outcomes for those who are marginalized in mathematics can enhance learning and improve outcomes for all students. Similar to intellectual merit and broader impacts, this could become part of the review criteria or an explicit section in all relevant solicitations that require proposals to address their contributions to advancing equity. It could also be an essential component of the project's broader impacts.

FND-AR 2: Establish a proposal process or competition focused on transforming findings from previously funded projects into policy and practice. To support this, funding organizations can do the following:

- Identify successful small-scale programs and provide resources to understand the conditions and partnerships needed to scale and support program expansion. These could include initiatives supported by COVID-19 funding. While many funding organizations have programs to support scaling, these should include structures or mechanisms to help others learn about these programs and support initiating scaling efforts by those who may not have been involved in the original project. They should also focus on the role of policy in supporting broad implementation of evidence-based practices.
- Create a repository of recommendations for policy and practice and the research that supports them. These should be promoted by in-person convenings or virtual webinars designed to disseminate findings with an explicit focus on building new partnerships that can expand this impactful work. Designated funding should specifically support others in implementing these recommendations in their own contexts or researchers expanding their work into new contexts with new partners. This should include those in a position to shape policy or efforts from researchers and practitioners to work with policymakers.
- Fund development of new centers or institutes that explicitly focus on bridging research, policy, and practice, or support existing institutes in building capacity for this work.

FND-AR 3: Eliminate the advantage of previous funding to encourage proposals from new PIs and nonacademic teams. Although it is important to demonstrate results when prior funding has been received, PIs or research teams with prior funding should not have an advantage within review structures and proposal requirements. Similarly, solicitations and funding requirements should encourage partnerships between different types of institutions to help increase the capacity of institutions that may not have the resources to support preparing and submitting competitive proposals and conducting related research.

FND-AR 4: Consider strategic ways to fund research on how to use AI and adaptive learning technologies to improve mathematics education. Although focusing on the technology itself is important, these funding mechanisms should recognize how rapidly this technology continues to change and include projects that focus on school, district, institutional, or collaborative infrastructures that can evolve appropriately with rapidly changing technology without placing a significant burden on K–12 teachers and higher education faculty. Additionally, funding should prioritize access, use, and development partnerships with communities that have historically been marginalized to ensure they are well served by ongoing innovation.

FND-AR 5: Partner with federal and state agencies to build coordinated efforts to incentivize cultural shifts and support progress through programs, policies, and investments. Culture shifts that prioritize equity-focused practices and elevate teaching and the teaching profession at all levels require systemic commitments and investments. Influence across all of the focus areas could be magnified through partnerships and coordinated efforts with federal and state agencies.

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