DOING THE MATH

Building a foundation of joyful and authentic math learning for all students

September 2019

100Kin10

THANK YOU

THANK YOU to all who made this report possible.

We are grateful to the Heising-Simons Foundation and CME Group Foundation for generously supporting this research, which will hope will inspire, moblize, and fuel the 100Kin10 network and the field to make meaningful changes that will engender joyful and authentic math learning for our nation's youngest learners.

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Their wisdom shines through; any mistakes or gaps, however, are strictly our own.

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> " MATHEMATICS; IT'S AN ADVENTURE, AN EXPLORATION, FORGING NEW PATHS INTO TERRITORIES NOBODY ELSE HAS LOOKED AT BEFORE."
>
> **NALINI JOSHI,** AUSTRALIAN MATHEMATICIAN AND PROFESSOR IN THE SCHOOL OF MATHEMATICS AND STATISTICS AT THE UNIVERSITY OF SYDNEY

MATH — and in particular grade-school math — elicits deeply negative emotions for many Americans, fueled by memories of rushing to finish a worksheet of times tables as the seconds tick down, tripping over the rules of multiplying and dividing fractions (*When do I flip the top and the bottom numbers?!?*), and using endless sheets of paper in an attempt to get to the bottom of a long-division problem. For most of us, freedom is not even in the same galaxy as math.

And yet research shows that math — and especially math for younger children — is a clear path to freedom. As individuals, a strong grasp of math concepts at an early age is not only a foundational building block and a gateway to STEM learning, it's also a major predictor of success later in school and in life.[1] A recent study by REL shows how math instruction in elementary school is more of a factor in the likelihood of high school graduates being college-ready in math than the coursework they engage in from Grade 6 forward.[2]

As Americans, math is a core element to building the workforce demanded by the 21st century, STEM-driven economy. As citizens of the world, it's essential to engaging more people, and particularly more people across race, class, gender, ability, and sexual orientation, in tackling the ever-growing environmental, social, and health challenges that threaten our current and future well-being. For this reason, among others, we must keep our students too often left behind in math (and STEM and education more broadly) front and center in this work, whether they are female, come from low-income homes or communities, have learning differences, or are marginalized because of their race, ethnic identity, or experience. All students need and deserve to experience math with joy and authenticity.

Teachers, proven to be the most important factor in a student's in-school learning, are a critical lever to helping all kids get access to foundational math, especially in the elementary grades.[3] They are positioned to help students connect with their natural curiosity and experience the joy of experimentation, problem-solving, and inquiry; see that puzzling, attempting, stumbling, learning, and improving are about growth, not failure; and grow into confident and emboldened drivers of their own educations and futures.

However, we know that many elementary students do not experience math with joy and authenticity, nor do their teachers. Too few elementary teachers receive the training and support they need to deliver joyful and authentic instruction to their students. As a result, too many students lack opportunities for effective math learning. Hung-Hsi Wu, professor emeritus of mathematics at the University of California, Berkeley, and former member of the National Mathematics Advisory Panel, notes, "We have neglected far too long the teaching of mathematics in elementary school. The notion that 'all you have to do is add, subtract, multiply, and divide' is hopelessly outdated. We owe it to our children to adequately prepare them for the technological society they live in, and we have to start doing that in elementary school. We must teach them mathematics the right way, and the only way to achieve this goal is to create a corps of teachers who have the requisite knowledge to get it done."[4]

If supporting elementary teachers to meet this challenge charges you up, you are not alone. Here at 100Kin10, we too see how critical it is to bolster our elementary educators with the knowledge, skills, and confidence they need to offer excellent math learning to all students, through improving preparation programs, professional development supports, and elementary-school environments.

We also have deep data that this is an essential issue to address to end the STEM teacher shortage and reach all students with excellent STEM learning. Over two years, 100Kin10 developed the Grand Challenges, an unprecedented roadmap of the underlying problems facing the STEM education landscape and the first-ever comprehensive ecosystem of a social sector problem. The map identifies the 100+ challenges and the "catalysts," the greatest leverage points for change across the Grand Challenges of the STEM teacher shortage. The catalysts reflect the synthesis of tens of thousands of data points on which issues, if improved, would generate a domino-like effect and the most improvement across the system. Two of the catalysts connect directly to foundational math: teacher preparation faculty who have expertise specifically in elementary STEM education and faculty modeling instructional strategies teachers will need to use in their classroom.

Armed with the knowledge of which issues are the highest-leverage, 100Kin10 has been mobilizing partners and allies to move the needle, one set of catalysts at a time. We began in 2018 with three catalysts related to nurturing positive work environments for teachers in schools. Even as our work on teacher work environments continues apace, 100Kin10 is now setting out to mobilize our network to tackle foundational math proficiency, guided by the question, "How might we equip elementary (PK–5th grade) teachers to enable authentic and joyful math learning for all students, especially girls, students from often-marginalized racial and ethnic backgrounds, and students from low-income homes and communities?"[5]

Our foundational math work — deliberately named to convey how essential math in the elementary years is to a person's academic, professional, and life opportunities, choices, and success — centers on two catalysts that address teacher preparation faculty's expertise in preparing elementary teachers. **One focuses on teacher preparation faculty who have expertise specifically in elementary STEM education.** In too many cases, teachers are taught by faculty who are disconnected from current elementary classrooms and math instruction. They lack an understanding of and experience with both the "what" (the content) and the "how" (the pedagogy) of foundational math teaching. **The second is about faculty modeling instructional strategies teachers will need to use in their classroom.** Pre-service teachers need to experience the type of instruction they will need to enact themselves, both because adults (and children) learn best when they are actively engaged and because these teachers were likely mostly exposed to more passive learning environments when they were students.

These catalysts are places of highest leverage, with the ability to have outsized impact across the system. They are not always the most obvious places to impact the system and are not, therefore, necessarily top of mind. It was in order to find these unexpect-

TEACHERS AT WORK

Research has pointed time and time again to teachers as the strongest in-school influence on student learning and development. But too often, we fall victim to the misimpression that schools must choose between student learning and teacher learning. Our deep research found that, in truth, schools can and should be places where both students and teachers thrive.

Recognizing this, 100Kin10 partners are together addressing three catalysts related to teachers' work environments in schools: relevant professional growth during the school day, opportunities to collaborate during the school day, and school leaders' responsibility for creating positive work environments.

Keep an eye out for connections between tackling foundational math proficiency and teacher work environments throughout the report. For more information, read our 2018 report "Teachers at Work," an analysis of the research surrounding teacher work environment in schools and the most promising collaborative opportunities for addressing these issues.

ed opportunities for high-leverage action that we conducted the Grand Challenges investigation in the first place, amassing and analyzing 35,000 data points over two years. The catalysts are the most efficient, impactful, and likely-to-succeed bridge between our current-state grievances (too few elementary students accessing authentic and joyful math learning) and our vision for the future: all elementary students experiencing authentic and joyful — and therefore effective — math learning.

While they are the places of highest leverage, the catalysts can be neither understood nor addressed in isolation. We confirmed through the course of our research that the catalysts are part of a larger foundational math puzzle that includes many pieces, ranging from course offerings to requirements of preparation programs, from ongoing professional learning opportunities for teachers and school leaders to societal beliefs. Understanding the ecosystem will allow us to make progress toward supporting elementary teachers to enable joyful and authentic math learning for all kids.

We began by getting smart on these topics, knowing that progress would only come from building on the wealth of what has already been figured out in the field, rather than starting from scratch. We combed through nearly 100 sources, including academic research, published reports, editorials, news articles, websites, and blogs, and we conducted interviews with nearly 20 leading practitioners and researchers. Most importantly, a Brain Trust of 35 100Kin10 partners and STEM teachers sat at the helm of this work, representing universities, alternative preparation programs, schools, museums, professional development providers, and more. Through virtual working meetings, one-on-one conversations, and independent review sessions, they advised our process and analysis every step of the way. All of this research was guided by four primary questions:

- What are the issues behind the lack of proficiency in foundational math?
- What has already been tried across the field to improve foundational math proficiency, and what do we know about what is and isn't working?
- How can individuals or organizations immediately apply these learnings?
- Taking into account the analysis of the influencing issues and existing or past efforts, where are there gaps in existing solutions, and where do new solutions need to be designed?

In the following pages, we introduce and explain what we're calling the foundational math ecosystem. The ecosystem paints the full picture of the issues keeping us from equipping teachers to enable authentic and joyful math learning, pulling both from the academic research and the real, lived experiences of the individuals working day in and day out to make elementary schools buzz with math energy. We take a deeper dive into the catalysts, offering more information and analysis on these highest-leverage opportunities. The report concludes by looking across the ecosystem to identify three crosscutting findings with corresponding calls to action: (1) Build vision and coherence around foundational math learning, (2) Revise expectations of elementary teachers' responsibilities, and (3) Bring foundational math into the 21st century. For each crosscutting finding, we articulate how the catalysts provide clear strategies for driving change.

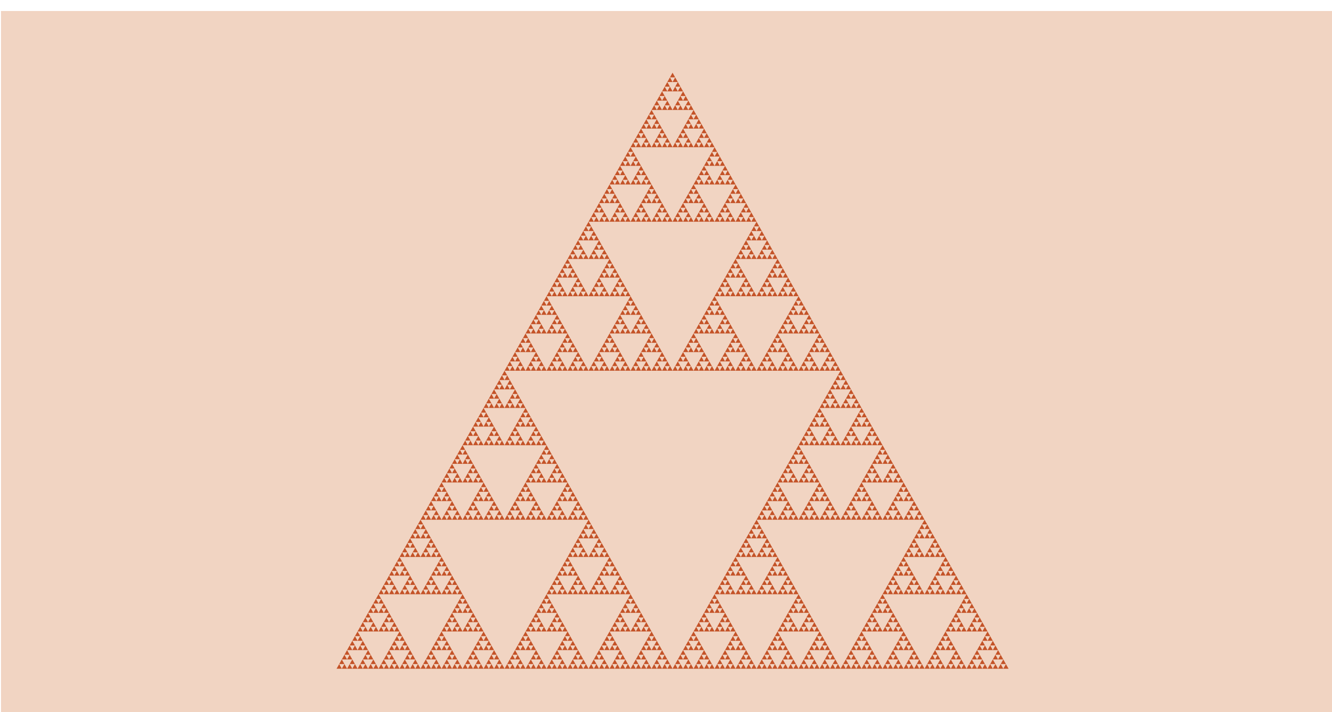
This report is intended to lay the groundwork and be the launchpad for diverse, coordinated, and mutually reinforcing efforts to improve foundational math. We hope it will inspire you to think about where you can save energy and avoid recreating the wheel by building on the field's existing knowledge, and where there are problems that might well need your particular expertise to contribute to solving them. Whatever you focus on, reach out to likely and unlikely allies and partner with them, because the problems are inter-related and thorny, and solving them in a sustainable, systemic way will take diverse partnerships with shared purpose. We intentionally designed the report to encourage this. It functions partially as a research report and partially as a workbook, offering spaces for you to jot down ideas or next steps as you read. We also envision this as the base layer of ongoing and living knowledge about foundational math that 100Kin10 partners and allies will continue to build on as they address these issues.

One final learning from this work, one that is more meta in nature: Although this research and the resulting report focus on foundational math, these issues do not exist in isolation from the other underlying causes of the STEM teacher shortage outlined in the Grand Challenges. In fact, they are highly related, and in particular the highest-leverage catalysts have strong ties across the system and to each other. This became clear as our findings often echoed what we heard during our investigation into the work environment catalysts. We believe that the parallels and connections we found are no coincidence, but rather further evidence of the systemic nature of these problems and the importance of addressing them in diverse and coordinated ways. You will notice several places throughout the narrative where we call out these synergies, with the intention of enabling more people to recognize and act on them.

In addition to these smaller callouts, we want to take a moment to point to one overarching insight that is emerging across our catalyst-focused efforts on foundational math and work environment for teachers. In order for teachers to enable authentic learning for students, they must first experience it themselves. We are so often laser-focused on student learning and what teachers need to do to impact student success that we miss the bigger picture. We need to ask what teachers need to *experience* to be able to create an environment that supports authentic learning for their students. How can we expect teachers to teach math with joy and authenticity if they themselves have only been exposed to rote math that prioritized memorization and following steps? How can we expect teachers to empower students to drive their own learning via active, engaging instructional strategies if they were never on the receiving end of these experiences? Harkening back to work environment, how can we expect teachers to create a space that values experimentation and failure as essential elements of learning if they themselves are not encouraged to experiment and learn from failure?

Writing in *Emergent Strategy*, Adrienne Maree Brown calls this fractals, "practicing at a small scale what we most want to see at the universal level," because "what we practice at a small scale can reverberate to the largest scale."[6] Teachers should be taught in the same ways we want our students to learn. We must create a work environment inside the school building that emulates the one we hope teachers will nurture inside their classrooms. How teachers experience their own professional learning will cascade and significantly influence how their students experience learning.

With that, dig in and join us. None of us can solve these challenges on our own, but if we coordinate and focus our efforts, we can succeed in preparing, supporting, and empowering elementary teachers to engage all students in authentic and joyful foundational math learning.



THE FOUNDATIONAL MATH ECOSYSTEM

MEET MARIA. Our journey with Maria begins when she is an elementary education major at her local university. As part of her required coursework, Maria takes one semester of a math "methods" course, taught by a professor within the school of education, that covers math pedagogy for grades PK through 5. The math content itself isn't too challenging, and the professor skims the surface on many of the more conceptual elements of the subject matter. Maria is also required to take two semesters of math content courses (there are six she can choose from) taught by professors in the math department. Her math professors have never taught below the university level and haven't stepped inside an elementary classroom since they were elementary-age children themselves. The coursework is confusing and disconnected from her methods course, leaving Maria frustrated with her own math skills, unsure about which concepts she will need to eventually teach to her students, and worried about if she will even be able to teach them.

During her field-based teaching experiences, also required as a part of her major, she is placed with a veteran third-grade teacher who closely follows the district mathematics scope and sequence. Maria had hoped to see examples of how to implement what she's learned in her pedagogy classes, but her mentor teacher's ideas around math instruction include mostly worksheets and computational rules. Maria is nervous about trying some of the interactive strategies that she learned in her methods class, and her mentor teacher gently recommends Maria follow her veteran approach instead.

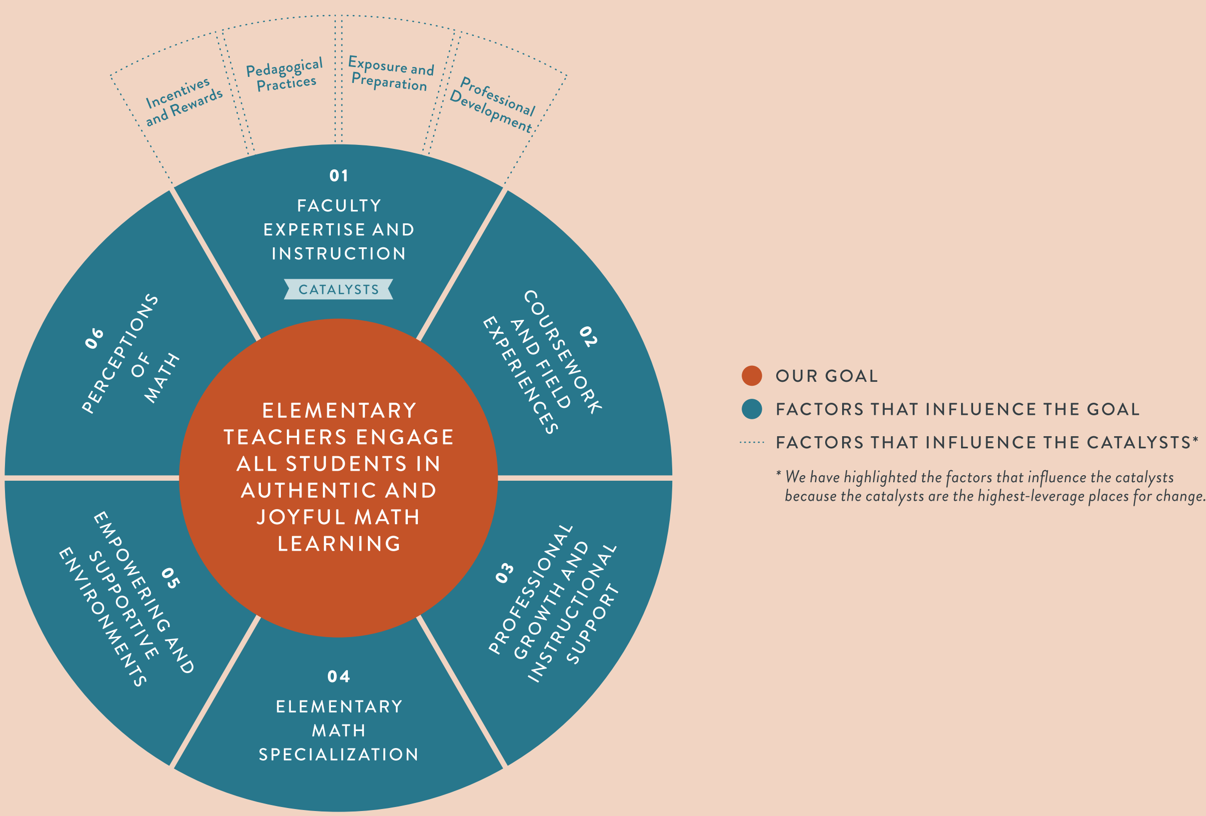
Upon graduating, Maria is solely in charge of her own second-grade classroom as a first-year teacher. Her confidence around math instruction remains low, and there is nowhere to turn for help, since there is no math instructional coach working in her school. She finds little encouragement to seek help elsewhere, as her school's annual instructional growth plan is focused on literacy goals. Moreover, her principal, who is not forthcoming with support to help Maria bolster her math skills or aptitude with authentic approaches to math instruction, urges her to focus on the school's literacy goals and follow the district's math program. Maria decides to go with the flow: She is new, after all, and has a lot to learn from those who've been around the block a few times. However, she notices that her students yawn when she announces it's time for math and become frustrated when they can't remember the steps for completing a problem. The girls in her classroom mostly exhibit uninspired obedience, following directions with little sign of the creativity or curiosity they show at other times of the day. Meanwhile, the boys who don't think they're good at math become a discipline problem. Her principal suggests she focus on improving her classroom-management skills, which she's heard is often a challenge for first-year teachers.

Six years later, Maria is the most experienced second-grade teacher at her school. She is the grade-level chair and is excited that her alma mater, the local university, has asked her to host pre-service teachers from the very education major she attended. When the student teacher asks her about authentic instructional strategies he's been reading about in some trade journals, a memory is triggered for Maria: Didn't she have a similar question when she was just beginning her career? However, Maria knows that it's best to go with the known path when teaching elementary school and suggests that he not try anything too experimental in his first few years of teaching.

While Maria is a fictional teacher, her experience mirrors that of countless elementary teachers in the United States. There are also many other stories we could tell, similar but with slightly different details: a school focused on improving its statewide assessment scores, or with good enough scores that it doesn't want to rock the boat with more interactive teaching practices; math professors who discourage their strongest students from pursuing a degree in education; and a system with a complete disconnect between what is needed to deliver the curriculum being taught in elementary schools and the training pre-service teachers are receiving during their preparation program.

Through all of this, a path forward emerges, where these stories become the exception and not the rule. That ecosystem looks something like this:

FOUNDATIONAL MATH ECOSYSTEM



As you can see, this ecosystem places elementary teachers and their ability to effectively engage all students in authentic and joyful math learning squarely in the center. This is what we aim to achieve. It describes six key factors, including support for teachers' ongoing learning and growth once they are practicing teachers, and the environment of the school and greater society that teachers work within. It highlights the catalysts that address teacher preparation faculty's expertise in elementary math content and modeling of instructional strategies, which we explained in the introduction, noting that these issues have outsized leverage across the system and thus are strategic places for action.

We believe that if all of us — preparation programs, teacher preparation faculty, elementary principals, district leadership, professional development providers, families, community members, students, and elementary teachers themselves — together address the factors included in the foundational math ecosystem, and in particular the catalyst factors, we could create a very different learning and teaching experience for elementary teachers. And in turn, students' interest in, love for, and success with math would soar.

The ecosystem includes key issues that emerged from our research, yet we recognize that such a picture is rarely exhaustive and that some factors that influence foundational math teaching and learning may be missing. Our purpose was not to create a perfect portrayal, but rather to provide perspective and research on the issues surrounding foundational math proficiency, to point to and encourage action on the highest-leverage catalysts, and to offer ideas for immediate action and an analysis of what will bring long-term change. Over the coming years, we will support 100Kin10 partners and allies to make progress on these issues, with a focus on the catalysts, and will continue to build on the learnings captured in this report through those efforts.

In the following pages, we present a description of what inhibits each of these factors, including an analysis of the current state of the field and brief descriptions of existing models that point to immediate actions that can shift to a more effective foundational math ecosystem.

HOUSEKEEPING

BECAUSE TERMS ARE IMPORTANT but also distracting and potentially divisive and derailing, we are taking a moment here in advance of the Research and Analysis sections to explain word choice throughout the narrative. The guiding question is: "How might we equip elementary (PK–5th grade) teachers to enable authentic and joyful math learning for all students, especially girls, students from often-marginalized racial and ethnic backgrounds, and students from low-income homes and communities?". When scoping this topic and forming this question, we landed on the terms "authentic and joyful" because of what we heard from 100Kin10 partners, teachers, and other stakeholders about what is essential to effective math learning. After completing the research phase, we continue to believe these terms capture the essence of what students need to excel in foundational math.

Effective math learning is **authentic**. In other words, kids need to internalize the concepts by constructing their own understanding of them and understanding how they connect to each other, other STEM subjects, and the world at large. That sort of real learning rarely results from rote instruction focused on memorization. Instead, research shows that it requires more engaging methods of teaching, and that students, especially girls and kids of color, flourish when exposed to more interactive lessons. There are many technical terms and styles of instruction that seek to achieve this authentic learning experience, including inquiry-based, active, problem-based, student-centered, hands-on, and more. This report is not intended to get into the debate among these various terms and methods, but instead to recognize the importance of moving away from more rote ways of teaching. Thus the report will generally refer to the idea of real math learning with the terms "authentic" or "interactive." However, we will use more exact terms in the context of describing specific research for accuracy.

Effective math learning is **joyful**. In recent years, as education has shifted to focus heavily on testing, many schools have unintentionally lost sight of the delight of cultivating the inquisitive minds of tomorrow. As a result, classrooms are more often filled with tasks and anxiety than with the energy and excitement that accompanies natural curiosity. Any parent knows that curiosity is inherent in children, and we believe that the joy kids find in learning needs to be restored to the classroom. This is especially critical for a subject like math, which seems to often be associated with negative feelings or criticized for its reliance on worksheets and disconnected from ideas that are relevant and meaningful to young children.

Secondly, teacher education can be complicated because of its many components. Preparation programs include subject-matter preparation, teaching methods or pedagogical training, field-based practicum experiences, and more. Many new teachers then receive support through induction programs for beginning teachers organized and administered by the district or school management organization they are hired by. And finally, ongoing education takes the form of professional development covering varying topics over the course of teachers' careers.[7]

Because different terms are often used to describe the various experts who contribute to teacher education, we want to articulate the ones we'll be using in this report. During their preparation programs, aspiring teachers receive instruction from multiple types of faculty members and other experts under the broad umbrella of **teacher preparation faculty**. First they are taught by **education faculty** situated within a university's school of education, whose own training and scholarship focuses on PK–12 education. Second, in many preparation programs, especially those that are university-based or that partner with a university, pre-service teachers take content courses taught by faculty in other departments (such as math). In this report, we refer to **math-content faculty** who reside in a math department and teach teacher candidates, and whose expertise and scholarship focus on math as a discipline. These math experts may be mathematicians, adjuncts, grad students, or other faculty or fellows.[8] It's also worth noting that teacher preparation faculty, and especially education faculty, also contribute to professional development programs and thus interact with in-service teachers. Teacher candidates also interact and receive guidance from current classroom teachers, their **mentor teachers**, during their field-based practicum and may also work with an expert serving to supervise their field-based experiences, with varying levels of direct connection to their other education faculty.

Notably, while alternative teacher-preparation programs also train a good number of teachers, these programs largely partner with university-based preparation programs or otherwise utilize faculty from those programs. Therefore questions about faculty expertise and instructional strategies carry over to alternative programs as well.

Finally, in many places in this report we refer to **elementary math specialists** and so share a definition of that role here. In recent years, the Association of Mathematics Teacher Educators (AMTE) — with support from the Association of State Supervisors of Mathematics, the National Council of Supervisors of Mathematics, and the National Council of Teachers of Mathematics — has placed significant focus on promoting the use of "Elementary Mathematics Specialists" (EMS professionals) in PK–6 environments, including publishing a set of standards that serve as a guide for credentialing and degree programs[9] and advocating widely for the use of EMS roles.[10] As part of their work, AMTE defines EMS professionals as "teacher leaders who are responsible for supporting effective PK–6 mathematics instruction and student learning." They note EMS professionals' roles and responsibilities may vary by context and needs.[11] In some places, we refer to specialists with a different term, such as coach, to maintain validity with a specific piece of research.

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[3] Teachers Matter: Understanding Teachers' Impact on Student Achievement. Santa Monica, CA: RAND Corporation, 2012. https://www.rand.org/pubs/corporate_pubs/CP693z1-2012-09.html.

[4] Wu, H. H. (2009). What's So Sophisticated About Elementary Mathematics: Plenty — That's Why Elementary Schools Need Math Teachers. American Educator, 32(3), 4-14

[5] Existing research varies in the grade levels it considers to be "elementary." In some cases, pre-kindergarten is included in elementary school research, and in others, it is grouped with the research base on early learning, generally thought of as ages 0 to 8. Similarly, Grade 6 is sometimes included in research on elementary school. We started with an intention to investigate across the PK–5 grade range to the extent these grades were included in the elementary school research base. Throughout the report, we have specified the grade ranges included in the research cited so as to accurately depict that research. Therefore, readers will see some variation in the ranges noted throughout the text.

[6] Brown, Adrienne Maree. Emergent Strategy: Shaping Change, Changing Worlds. AK Press, 2017, 22, 52.

[7] Newton, X. A., Jang, H., Nunes, N., & Stone, E. (2010). Recruiting, preparing, and retaining high quality secondary mathematics and science teachers for urban schools: The cal teach experimental program. Issues in Teacher Education, 19(1), page 24.

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[11] McGatha, M & Rigelman, N. (Eds). (2017). Elementary mathematics specialists: Developing, refining, and examining programs that support mathematics teaching and learning. Association of Mathematics Teacher Educators. Charlotte, NC: Information Age Publishing, Inc.

Some Early Math Specialists work exclusively with students, either in classrooms teaching math in one or more grade levels or with small groups of students to provide remedial or enrichment support. Other EMS roles work primarily with teachers at the school or district level, serving as coaches to provide professional development or support school- or district-wide improvement plans. Some school-based roles may combine a student-facing and teacher-facing orientation. And yet other EMS roles may focus on curriculum, assessment, and/or policy development at the district or state levels.

RESEARCH & ANALYSIS

01 FACULTY EXPERTISE AND INSTRUCTION

How might we increase teacher preparation faculty's expertise in elementary math content and pedagogy and use of effective instructional strategies in their own courses?

CATALYSTS

02 COURSEWORK AND FIELD EXPERIENCES

How might we engage aspiring teachers in a sufficient number of high-quality courses and field experiences that are coordinated across content and pedagogy, and that are aligned to standards and authentic approaches to teaching?

03 PROFESSIONAL GROWTH AND INSTRUCTIONAL SUPPORT

How might we enable school and district leaders to provide instructional leadership in mathematics and to support teachers with professional growth opportunities, curriculum, and other resources to continue growing in math content knowledge and pedagogy?

04 ELEMENTARY MATH SPECIALIZATION

How might we increase the number of elementary math specialist roles in schools and the training and support for these roles from districts, states, and preparation programs?

05 EMPOWERING AND SUPPORTIVE ENVIRONMENTS

How might we foster elementary school environments where teachers are empowered and supported to teach math (and to lead the teaching of math) in authentic and joyful ways?

06 PERCEPTIONS OF MATH

How might we engender widespread belief that math is an essential subject for all citizens, not just for a few?

01

FACULTY EXPERTISE AND INSTRUCTION

CATALYSTS

How might we increase teacher preparation faculty's expertise in elementary math content and pedagogy and use of effective instructional strategies in their own courses?

ASPIRING TEACHERS receive instruction from multiple experts in a diverse set of contexts over the course of their preparation. With so many different instructors, plus the range of expertise each brings to their unique role in a candidate's overall preparation, the extent of these instructors' specific expertise in elementary math content and pedagogy and in modeling effective instructional strategies for elementary math teachers is a critical determinant of how prepared elementary teachers will be to deliver authentic and joyful math instruction to their students. Research has demonstrated the critical role teachers play in student learning throughout PK–12, and the same can be said for the importance of faculty to students in teacher preparation programs.

Elementary teacher candidates are tasked with providing foundational knowledge across several key content areas to our young students, and need specific training in relevant content and pedagogy to be sufficiently prepared. Their instructors therefore require expertise in these same areas.

Because education is a practice-based field, candidates must also see their instructors modeling effective strategies and have opportunities to become immersed in high-quality practice-based experiences. To return to the idea of fractals introduced at the start of the report, just like their future elementary students, teacher candidates need to be taught how to teach in ways that are aligned to the best research from the science of learning. Moreover, the impact of teacher preparation faculty's reach is broad, given many faculty not only instruct pre-service teachers but also work with practicing teachers through providing professional development and recertification courses. As a result, the influence of their expertise and choice of instructional strategies extends broadly throughout much of the teacher workforce.

Yet research demonstrates that many faculty are insufficiently prepared and lack the needed experience and contextual knowledge to prepare prospective (and current) teachers to teach foundational math.

WHAT CAUSES THIS PERSISTING ISSUE?

01 Higher education rewards research and scholarship over achievements related to teaching, which is especially visible in the criteria for tenure.

02 Relatedly, there continues to be resistance to reforming teaching styles and adopting more innovative pedagogical practices in most universities.

03 Few math faculty members have formal training in math education or in preparing math teachers, nor are they well-versed in the best current research on the science of learning and effective pedagogy, or even aware of what current math instruction looks like in PK–12 schools.

04 Faculty members rarely receive professional development to support their role as teacher educators.

First, the longstanding and well-documented culture within higher education that rewards research over teaching, particularly for tenure decisions, has a strong impact on teacher preparation. At a foundational level, the prioritization of research and scholarship, and specifically the prominence they play in tenure policies for faculty, works to direct the attention of faculty away from their teaching and any other efforts to improve their knowledge or practice as instructors of teacher candidates. Graduate schools preparing future faculty members continue to emphasize scholarship and research, serving to perpetuate the "publish or perish" culture in higher education.[12] As tenured professors receive little reward for other activities, such as service projects, teaching, or their own professional development, there is little to motivate teacher preparation faculty within the university setting to seek out additional contextual knowledge or experiences or to focus on mastering the pedagogy aligned to the needs of elementary teacher candidates. These efforts instead must come largely from intrinsic motivation. For junior faculty members working toward tenure, not sacrificing research time for other activities is seen as essential to their success.[13] While these issues are pervasive throughout higher education, they are prominent within STEM fields, where faculty members commonly devote the majority of their early career to specialized research.[14]

As a result of the prioritization of research within higher education, even faculty situated within schools of education may not be well-connected to the current realities of teaching in a PK–5 classroom, or insufficiently equipped to model and support teacher candidates to deliver authentic, student-led instructional approaches. Schools of education, even with their explicit mission to prepare teacher candidates for the practical world of teaching, often still require their faculty members to exist within an academic world that prioritizes research and scholarship. David Labaree, a professor in the Department of Teacher Education at Michigan State University, describes the "cultural clash between the worldviews of the teacher and researcher" when discussing challenges inherent to trying to simultaneously hold both the practitioner and research perspectives.[15] This dual focus may be challenging for some education faculty members. When added to the likelihood that they are less able to spend time in schools engaging with students, or may be several years from their last direct experience as a PK–12 classroom teacher, this may leave them less in touch with current research on how children learn or the most effective pedagogical methods, and therefore less able to prepare candidates in these methods. Education faculty, in some cases, also may not have the mathematical content knowledge needed to most effectively teach math methods courses, particularly given the significant shifts in recent years in the field's conception of math as conceptual rather than purely procedural.

Second, a related point: Even given the predominant culture and policies around research and tenure, many acknowledge the need to improve STEM faculty members' teaching strategies to be more learner-centered for undergraduates taking courses in these fields. We know the importance of aspiring teachers experiencing learner-centered instruction during their preparation. The recent research brief commissioned by 100Kin10, "STEM Content and Pedagogy Are Not Integrated," summarizes research showing the relationship between exposure to inquiry-based STEM pedagogical practices during teacher preparation and increased student achievement. The specific needs of elementary teacher candidates for more effective and learner-centered instruction from their math content faculty may be significantly more pronounced, given, as our Brain Trust and expert interviews note, their likely lack of prior knowledge and confidence in math, and that they need to not only gain new content knowledge but ultimately the capacity to translate and apply that content knowledge effectively within PK–5 classrooms.

Yet recommendations for STEM faculty to use more interactive approaches within teacher preparation programs have not yielded an increased use of these instructional strategies, even when faculty members express a deep commitment to teaching and to their students.[16] As Kate York, master teacher at the University of Texas at Dallas–UTEACH Dallas notes, "Even in cases where pedagogical methods coursework is grounded in progressive, inquiry-based STEM approaches, pre-service teachers' STEM content preparation is still largely delivered through traditional 'stand and deliver' instruction. This inconsistency in how one is taught and how one is being taught to teach can impact teacher candidates' overall learning success in the content area and send mixed pedagogical messages about what constitutes good teaching practice."[17]

Third, math faculty responsible for teaching candidates math content often are unfamiliar with the context of PK–12 schools and importantly the content and pedagogy elementary teachers need. Our research points to significant questions about the extent to which the math faculty largely responsible for teaching content courses are sufficiently prepared and knowledgeable to do so. Math content faculty supporting elementary pre-service teachers often do not have formal training in math education or preparing teachers, nor do they have experience teaching mathematics to students in grades PK–5. They likely have little knowledge of the science of how children learn math and more generally are not well versed in the current literature and best practices surrounding elementary education and math instruction in particular. And they are rarely provided any training in advance of teaching math content courses to aspiring teachers.[18,19,20] A recent study by Appova and Taylor reported more than half of math content faculty who teach content courses to aspiring teachers feel unprepared and report lack of training, resources, and support at their institutions: "Trained as mathematicians or as teachers themselves, most teacher-developers lack knowledge about teachers as learners."[21] This lack of knowledge and training can significantly hinder their ability to be effective instructors of elementary teacher candidates.

In a study intended to investigate whether disciplinary faculty participating in the National Science Foundation Math and Science Partnership (MSP) program have the knowledge and expertise to effectively engage with high school teachers, Zhang et al. describe learnings from longitudinal case studies of eight MSP projects. One tenet of MSP programs is the engagement of STEM content faculty with practicing teachers via involving these faculty in providing professional development to teachers. The study illuminates the extent to which disciplinary faculty lack both the expertise and experience to effectively instruct teachers. One partnership leader, a chemist by training, noted that "STEM faculty are typically clueless [about teachers]. They don't understand the content needs of K–12 teachers. They don't know where to start. And once they've gotten started, they don't know where to go." Disciplinary faculty participating in the program acknowledged having little knowledge or experience with aspects of PK–12 STEM education pedagogy prior to participating in the MSP program, as well as having little knowledge about school contexts, student populations, and state curriculum standards and assessments. They also noted how, as a result of the program, they had now been exposed to existing research in the field of science and mathematics education. One faculty member commented, "I was under the mistaken impression that pedagogical research was at a lower level and was paper-thin. I now have an appreciation for the importance and depth of pedagogical research."[22] While this example describes faculty interactions with high school teachers, one can infer that disciplinary faculty face similar if not more marked challenges working with teachers of younger students.

Fourth, teacher preparation faculty receive little if any ongoing professional development for their role as a teacher of teachers. Again, the prominence of research within higher education institutions plays a large role. With research seen as the clear priority for faculty within higher education institutions, providing professional development for faculty was seen as a distant third behind teaching of undergraduates. In fact, sites participating in the Math and Science Partnership programs sought specifically to provide professional development to participating faculty to support their ability to effectively partner with practicing secondary teachers. One senior STEM university faculty member noted, "This is the methods class that I've never had before."[23] Yet institutions have little motivation to provide professional development to improve faculty understanding of elementary math and how to most effectively teach candidates, in particular while faculty are striving for tenure. And once faculty receive tenure, there remains little incentive, interest, or resources for faculty to improve their own practice and remain up to date on current literature and practices related to PK–12 instruction.[24]

As the research above shows, these problems are not new. Nor are they unknown to those working to prepare teachers, as is clear from several decades' worth of acknowledgement. Over 30 years ago, in 1986, a group of university deans formed a coalition, which they named the Holmes Group, calling for reform in their own schools of education to improve the training of future teachers. Nearly every dean of the about 100 universities invited to join the Holmes Group signed on, but their efforts seemed to fizzle in the late 1990s. In 2006, Arthur Levine, former president of Teachers College at Columbia University, stated, "Graduates are insufficiently prepared for the classroom."[25] And half of education school professors asked in a 2010 Fordham Institute survey agreed that "teacher education programs often fail to prepare teachers for the challenges of teaching in the real world."[26]

HIGH TECH HIGH

High Tech High (HTH) opened as a single-site public charter school in 2000 and has grown into a network of 16 schools serving over 5,200 K–12 students in San Diego. HTH utilizes a project-based learning model and is guided by the design principles of equity, personalization, authentic work, and collaborative design. HTH applied for and was approved by the California Commission on Teacher Credentialing to offer the HTH District Intern Program in 2004, awarding preliminary single-subject certifications. In subsequent years, the HTH program was approved to offer preparation in multiple subject (K–8) and education specialist certification areas.

The Intern Program is a job-embedded, two-year preparation program where participants serve as classroom teachers and complete coursework in the evening. The Intern Program teaches a project-based pedagogy founded in equity and inclusive learning. Most importantly, candidates are learning directly from classroom teachers who can help them integrate content knowledge with pedagogy. Candidates are also supported by their on-site mentor and have the opportunity to observe these master teachers and to be observed by them as well. Those who successfully complete the program are awarded a preliminary teaching credential, identical to the same credential awarded by a college or university.

The Intern Program ensures candidates engage in several ways with faculty who have specific expertise in preparing elementary teachers to teach math. First, the elementary math course is co-taught by two teachers, an elementary teacher and a middle-school math teacher. Given that multiple subject teachers earn a K–8 credential, HTH finds it important to prepare them in the wide range of mathematical instruction they could potentially teach. In this math course, participants explore how to construct learning experiences for students that develop the habits, dispositions, skills, and content knowledge relevant to math. Participants become familiar with pedagogical approaches to teaching academic content that develop inquiry, critical thinking, creative problem-solving, differentiation, collaboration, and communication skills in regards to math in the classroom. Through the design of open-ended, student-centered, constructivist learning experiences, participants investigate how to integrate authentic teaching, learning, and assessment of foundational skills within numeracy.

The program is also designed around three core elements that support candidates' effective engagement with faculty:

01 **Put It To Practice.** Instructors design learning extension activities in which participants design curriculum or implement a strategy they learned in class in their own classroom, and return to their next session to share and reflect. In addition, not only are participants experiencing these strategies via instruction that should be modeled in the classroom, but participants have an opportunity to try it out in class with their peers and instructors.

02 **Collaboration.** The course is designed in collaboration with the two instructors and the program director in order to discuss new teacher needs, as well as current pedagogical and mathematical shifts in education, including within the various districts we support.

03 **Participant Feedback.** Course instructors receive weekly feedback from participants, and participants have an opportunity to pose questions and discuss their needs for consideration for the following week's lesson, providing a truly personalized approach for participants.

If universities are aware of the need to change, why have more not done so? We believe that universities preparing our nation's teachers act out of goodwill and want to do right by their graduates and the students they will serve. We therefore looked to systemic impediments that might be inhibiting the capacity for or ease of change.

There is a clear disconnect between teachers' performance in schools and those responsible for preparing them. Preparation programs are rarely held accountable for the success of their graduates,[27] and while recognizing the negative implications of accountability, a complete void of it may demotivate programs to make changes to their approach. Even when they are motivated to change, preparation programs often face obstacles to doing so. Many are unable to access data about the performance of their graduates, as half of states do not share teacher performance data with preparation programs even though they collect it.[28] On top of all of this, there is insufficient research for how to design an effective teacher preparation program. As a recent report from Bellwether Education Partners points out, research has historically centered on candidate and program inputs, using a similar idea as law and medicine that these requirements will ensure that a candidate meets a certain quality threshold.[29] However, the past couple of decades have proven that there is little correlation between these inputs and student learning. As a result, the field has started to look to the performance of program completers to discover what works. Thus far, though, these efforts have met with limited success, mostly because there has been more variation among candidates who attend the same program than among those who graduate from different programs.

Preparation programs also face the change-inhibiting inertia common to large organizations. This barrier is key, as many preparation programs need to make significant changes to their model, not just tweak it, and that's not an easy undertaking in an established institution. The Clayton Christensen Institute argues that by asking teacher preparation programs to shift their measure of quality "from course offerings to objective measures of graduates' teaching skills, we are asking schools of education to do a job that is fundamentally different from the job they were designed and built to do."[30] High turnover among leadership makes this inertia that much more difficult to overcome. Deans and directors of education have the highest turnover rate among college administrators tracked by Higher Education Publications, Inc. since 2016. With a 22 percent turnover, deans and directors of education have greater turnover than provosts (21 percent) and presidents and chancellors (18 percent).[31]

Finally, as the ecosystem image above illuminates, these problems are interconnected and mutually reinforcing. Our efforts to address them have largely been piecemeal and disconnected. It should perhaps come as little surprise, then, that those disconnected and isolated efforts do not lead to lasting change. Our research distilling the shared elements of change efforts that succeed and are sustained over time pinpoints the importance of diverse organizations working in coordinated ways on the multiple, interrelated elements of any challenge.

Although it is generally true that there has been too little progress on these issues, some teacher preparation programs and other organizations are actively working to better equip education faculty to model authentic instructional practices with candidates. For example, TeachingWorks at the University of Michigan partners with teacher preparation programs to offer professional development to teacher educators to improve their capacity to use practice-based methods to prepare beginning teachers, thus allowing beginning teachers to engage in practice before they enter the classroom.[32] For more information, see the spotlight on TeachingWorks found later in this section. Similarly, High Tech High's teacher preparation program utilizes a job-embedded intern approach. Program participants are employed as the teacher of record while learning from experienced classroom teachers who can help them integrate content knowledge with pedagogy, being supported by an on-site mentor, and having the opportunity to observe and be observed by master teachers.

There is a scarcity of teacher preparation faculty with expertise in elementary STEM education, making recruitment and selection of faculty with sufficient expertise challenging. Zhang et al. report changes in hiring practices at some higher education institutions to prioritize the combination of discipline and education expertise, in an effort to recruit faculty who are interested in teacher preparation or whose research interests include the instruction and/or engagement of teacher candidates. For example, some institutions created tenure-track positions for teacher preparation faculty or STEM education researchers within STEM departments. Yet they also note that departments attempting to prioritize a combination of discipline and education expertise in faculty hires "have found it to be an 'exceedingly difficult and competitive' undertaking due to both the lack of people with these credentials and the increasing number of IHEs [Institutes of Higher Education] attempting to attract those who are available."

HOW YOU CAN TAKE ACTION

- **Elementary math teachers and teacher preparation faculty** can together take part in learning communities where they exchange knowledge and resources to improve their math instruction, whether they are teaching in elementary or university classrooms. One interesting model of this is Math Teachers' Circles, which brings together K–12 math teachers and mathematicians (including math education faculty who teach aspiring teachers) to work on rich mathematical problems and build partnerships.

- **Teacher preparation programs** can experiment with offering professional growth opportunities to their faculty focused on developing authentic instructional practices, integrating elements of the Teacher Educator Practice Framework. Supported by the Bill & Melinda Gates Foundation, the National Center for Teacher Residencies partnered with three other organizations to develop the Framework, a set of 12 practices that outline the skills and abilities teacher educators must have to improve novice practice. Teacher preparation programs can also support more informal growth opportunities, such as faculty members meeting to share tips and ask questions about instructional strategies. For example, IDEAS at Rider University brings together science, mathematics, and education faculty at monthly meetings to discuss how to teach their courses in ways that are more authentic.

- **Math and math-teacher associations** can partner with universities to host workshops for faculty on math education research–based pedagogy. The American Physical Society, American Astronomical Society, and American Association of Physics Teachers host a similar opportunity for physics and astronomy faculty.

- **Universities and other preparation programs** can invite teachers to serve as guest lecturers or host faculty in their classrooms, which will, in an engaging way, supplement faculty understanding of what elementary math learning looks like. (This could be especially fun for teacher alumni to do in partnership with their prep programs.) Also, this tactic has the added benefit of increasing connections between the preparation program and local schools.

- **Elementary teachers** with expertise in foundational math instruction can become course instructors. This supports district, school, and preparation program leadership to identify common requirements for strong elementary math instruction, but also requires that they work together to find a way to offer release time to the teachers. The High Tech High Graduate School of Education and the Relay Graduate School of Education are examples of preparation programs that use practitioner faculty.

ACTIONS I WILL TAKE...

FIRST STEPS TO GET THERE...

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TEACHINGWORKS, UNIV. OF MICHIGAN

For readers who may not be familiar with your organization and work, please provide a brief description of your organization.

TeachingWorks is a sponsored research center within the University of Michigan School of Education dedicated to the right of every child to have skillful teachers in school. Every day, thousands of children — especially Black, Latinx, and Native American children, and children living in historically marginalized and underserved communities — miss out on educational opportunities because of their teachers' unequal access to high-quality preparation and support. TeachingWorks is dedicated to improving teachers' preparation and to creating a professional threshold for entry to teaching.

Our goal is to create a system for teacher preparation and support that will make commonplace skillful teaching that disrupts inequity. We know that establishing such a system can only happen if we work collectively. Thus, we have partnered strategically with researchers, scholars, practitioners, policy makers, school districts, alternative and traditional teacher preparation programs, and teacher preparation centers from across the country. Through these various partnerships, we have supported efforts to identify and learn practices of teaching that are particularly high-leverage for children to flourish. We have offered professional development, training, seminars, and consultations to support teacher educators in learning practice-based methods to prepare teachers. We also develop resources and tools to support the work of professionals who support teachers to develop their practice. Through this collective work, we aim to contribute to achieving the vision of a just and equitable public education system, one that makes possible a better tomorrow for children and young people everywhere.

How is your organization working to improve foundational math?

TeachingWorks is working to improve foundational mathematics through a variety of partnerships and projects. TeachingWorks has established two multiyear, application-based teacher preparation fellowship programs for networks of teacher education faculty in Minnesota and California. The goal of both programs is to introduce teacher educators to key tools in designing and implementing practice-based teacher education in mathematics, and to support instructors in a first experience in using practice-based pedagogies (such as rehearsals, simulated student interaction, analyzing video, etc.) to teach novices high-leverage teaching practices with careful and explicit attention to advancing justice. With support from TeachingWorks, admitted fellows, many of whom are elementary mathematics methods course instructors, are working on developing and implementing course materials and instructional approaches that focus on the interconnections of specific high-leverage practices, mathematical knowledge for teaching, and equitable access to excellent mathematics instruction.

As they design and try out their instructional units, fellows are receiving a combination of remote and in-person coaching and support from TeachingWorks, such as workshops, class observations, and curriculum review to assist them in connecting various teacher education pedagogies to supporting teacher candidates' learning of teaching practice.

For example, our methods course fellows in California were excited about the opportunity to work on content, teaching practice, and equity all together, but they were also concerned about the things they would have to cut from their syllabi to achieve this focus. We needed to find a way to show participants how they could better structure their curricula to layer in content, practices, and advancing justice. Our solution was hosting a mathematics methods laboratory class at California State University, Fullerton. While members of the TeachingWorks team taught a mathematics methods course to 20 teacher candidates from the CSU–Fullerton campus, fellows in the partnership, as well as stakeholders from the entire CSU system, observed the class to see firsthand how to integrate mathematical content, the high-leverage practices, and attention to equity within teacher education. In afternoon professional development sessions, fellows worked with the TeachingWorks instructional team to unpack each day's lesson, highlighting the specific pedagogical moves that opened opportunities for novices to practice teaching toward the disruption of inequity. We've since expanded the laboratory classes to include our methods course fellows from our Minnesota teacher education fellowship.

Additionally, for 16 years, TeachingWorks has hosted elementary mathematics laboratory classes throughout Michigan and the United States. The Elementary Mathematics Laboratory (EML) enables educators and education advocates to see the complex work of teaching in real time. EMLs typically feature a one- to two-week elementary mathematics class taught by TeachingWorks director Deborah Loewenberg Ball to students from school districts in areas near the host site. EMLs are attended and observed by teachers, school and school district leaders, teacher educators, and policymakers from across the country. The EML program is designed to provide participants an authentic, firsthand experience of designing and implementing lessons that incorporate the TeachingWorks high-leverage practices and specific teaching moves that can disrupt patterns of inequities in classrooms. Each morning before the class, EML participants work with the instructional team in a pre-brief session, in which they examine, discuss, and refine each day's lesson plans and strategies for the instruction. They also work in small groups to try out the mathematical problems and tasks the children will later complete, making note of specific responses from children and teaching moves from the instructional team they would analyze during the class.

After each morning class, EML participants do a gallery walk of the classroom, where they analyze student work and note their responses to the mathematical tasks they completed in the morning. They then meet again with the instructional team to debrief the day's lesson, ask questions, and reflect on the teaching practices and strategies they observed. In the afternoon, EML attendees have the option of attending a variety of specially designed professional development sessions on facilitating mathematics discussions, examining children's mathematical thinking, and learning strategies for instructional leadership through the high-leverage practices. The sessions are structured to emphasize key teaching moves participants observed in the morning laboratory class, and to help teacher educators and school administrators to develop specific strategies for coaching and supporting beginning teachers.

Lastly, to widen access to instructional materials for practice-based teacher education, TeachingWorks is launching the TeachingWorks Resource Library. Teacher educators, including elementary mathematics teacher educators, can use this website to find high-quality, practice-based teacher education curriculum resources. The site offers more than 20 full units of instruction across grade levels and content areas, each including ready-to-use activities with videos, lesson plans, PowerPoints, observation tools, and other supporting materials, designed to support the development of skillful teaching that disrupts patterns of exclusion and injustice in classrooms. For example, teacher educators looking to introduce their novices to the practice of leading a group discussion in elementary mathematics might download a lesson plan that includes tools for watching and analyzing a classroom video with their students. The site is free and open to all teacher educators across levels of experience with practice-based teacher education. The resource library will be regularly updated with new materials as TeachingWorks continues to research and learn from students, teachers, and teacher educators.

What is core to your work? What elements are critical to its success?

At the core of our work is ensuring that attention to justice inside of teaching and learning isn't peripheral, but instead integrated carefully together with content and teaching practice. We are also focused on actually engaging with practice, mathematical content, and advancing justice instead of just talking about, reading about, or watching practice. Still, using concrete and authentic examples of teaching practice, such as video, in which the children are predominantly children of color, is central to ensuring our work is closely aligned with the various contexts within the U.S. that many teachers will go on to work in.

As you look to the future, where are you planning to improve or expand to make a bigger impact?

Over the next few years, we hope to continue extending our reach in developing usable materials and online learning opportunities that draw on our deep engagement in actual teaching and learning. Additionally, we recognize our elementary mathematics laboratories are valuable sources of professional learning for the complex work of elementary mathematics teaching. In the future, we hope to build our laboratory classes to be a sustainable form of professional development that includes tailored follow-up with participants. Lastly, we hope to develop ways for the mathematics laboratory classes to be a resource for teacher preparation, policymaking, and public communication about mathematics instruction and learning.

About Spotlights

This research identified several organizations and models currently working to better equip elementary teachers to enable authentic and joyful math learning for all students. While these spotlights are at different points in their development and implementation, we believe all are promising places for the field to learn from when considering how to make progress on foundational math proficiency. 100Kin10 compiled these spotlights by inviting organizations to share core elements of their foundational math work through an interview-style questionnaire.

02

COURSEWORK AND FIELD EXPERIENCES

How might we engage aspiring teachers in a sufficient number of high-quality courses and field experiences that are coordinated across content and pedagogy, and that are aligned to standards and authentic approaches to teaching?

ELEMENTARY TEACHER PREPARATION PROGRAMS, given both the nature of the teaching roles their candidates will eventually fill and state licensure requirements for elementary grades, must expose candidates to a wide range of content and pedagogy to prepare them to teach across multiple grades and subject areas. Yet the majority of undergraduate teacher preparation programs do not adequately cover the content knowledge needed for elementary teachers to effectively teach foundational math. Without a strong foundation in relevant content and pedagogy, elementary teachers begin their careers at a great disadvantage, ultimately decreasing student learning and their likelihood of remaining in the profession.

WHAT CAUSES THIS PERSISTING ISSUE?

01 Elementary candidates overall are required to possess a depth and breadth of knowledge needed to teach math across all PK–5 grades in addition to similarly extensive knowledge in other subject areas, an expectation that may be unreasonable on both candidates and the programs that are preparing them.

02 State requirements for elementary educator licensure mandate sparse training in math, resulting in many preparation programs and their faculty failing to address the depth and breadth of knowledge needed.

03 Many preparation programs lack alignment among math content courses, pedagogy courses, and instruction-based practicum, resulting in little coherence across a teacher candidates' preparation experience.

04 Mentor teachers are tasked with instructing candidates with little information or support to do so, leaving candidates and mentor teachers responsible for determining the day-to-day path of the practice experience.

First, elementary teachers are expected to possess the expertise needed to teach a wide range of content, not only within math but across other subjects as well. Multiple-subject credentials allow teachers to teach all grades and all subjects on the PK–8 continuum.[34] As our Brain Trust noted, exploring mathematics content and pedagogy across all these grade levels at the depth needed for elementary teachers, most of whom do not have other post-secondary training in math, would require candidates to take significantly more courses than are offered or required by their preparation program. Rather, preparation programs largely cannot address the full range of learning candidates require to be prepared to deliver meaningful, authentic math instruction. Given the expectations required for multiple-subject credentials and the time available to cover math content and pedagogy (given all the other subjects that must also be covered), preparation programs are limited in their opportunity to bolster teacher candidates' foundational understandings of math, an area of need for many elementary candidates.[35] As a result, teachers often do not leave their preparation programs with a conceptual understanding of math, either as it spans the PK–12 curriculum or as it connects to other STEM (or non-STEM) subjects.

Second, state requirements for elementary-educator licensure mandate sparse training in math, which in turn drive the requirements of most preparation programs. As of 2017, only four states required elementary school candidates to have a major, minor, or concentration in a core area instead of a generalized elementary degree. Requiring elementary teacher candidates to concentrate in academic subject areas, through taking more and higher-level courses, is an important step towards ensuring elementary teachers have the necessary foundation to effectively teach college- and career-ready standards across all subjects they are responsible for.[36] Without state-level requirements pushing preparation programs to alter their coursework, candidates by and large do not take a sufficient number of math content courses, nor cover the full breadth and depth of knowledge they require in their courses. In a review of 817 undergraduate programs' approach to elementary content knowledge, the National Council on Teacher Quality found that only 1 in 4 programs covers the breadth of mathematics content necessary for elementary grades, and 23 percent do not require a single course in elementary math content that could be considered aligned with the needs of elementary teachers.[37] Further, during the licensure process, many states require teacher candidates to take an exam to assess if candidates have the necessary conceptual knowledge to teach elementary mathematics. Yet the math content on licensure exams is often misaligned with the specific knowledge elementary teachers need, and just about half of states either do not require a separately scored math test or require no math test at all.[38]

Third, many teacher preparation programs lack alignment among math content courses, pedagogy courses, and instruction-based practicum. On one level, research shows pre-service programs lack critical alignment between math content courses and methods or pedagogy courses, which is often a result of a disconnect between the math department and the education department (with similar disconnects happening between content and pedagogy teachers of other STEM subjects as well). In many programs, faculty members in the math department teach math content courses, and education faculty teach methods courses. As described earlier, math faculty in particular often have little knowledge of standards-based, authentic instructional practices and of the realities of how elementary age students learn math. Therefore candidates receive instruction in math content that is not aligned with what they are learning in their methods courses, nor with current notions of how to teach foundational math in authentic and joyful ways.

On another level, there is too little coherence between what teacher candidates learn in their courses and what they experience in the field. Research on teacher education has long acknowledged the "tensions between teacher education programs and the realities faced by teachers in K–12 schools."[39] Chief among these tensions is the disconnect candidates experience between the content and pedagogy covered in their courses and what they observe and participate in during their field experiences, with little communication and coordination happening between faculty, teacher mentors, and those supervising field experiences. Many candidates find that the schools or districts where they are placed for field experience, and the teachers serving as their mentors, hold differing or even opposing views about what constitutes good teaching and high-quality curriculum and instructional materials. Many saw these tensions deepen as a result of heightened accountability pressures brought on by No Child Left Behind and continued to see gaps widen in the era of standards-based instruction.

Fourth, mentor teachers play a significant role in candidates' field-based experiences, yet receive little information or support to do so. Whitenack and Swanson reported candidates commented frequently that their mentor teachers often do not teach in the ways they learned in their methods courses, and that this often was related to mentor teachers closely following district pacing and curriculum guides. Some candidates reported working with mentors who followed the district's norms of teacher-centered instruction, rather than modeling more authentic, student-centered approaches, while other mentors who did use more authentic approaches were seen as "resisting" the district-preferred approach.[40] Zeichner notes even in cases where candidates have multiple field experiences within a program with school-university partnerships, "it is very common for mentor teachers with whom students work during their field placements to know very little about the specifics of the methods and foundations courses that their student teachers have completed on campus, and the people teaching the campus courses often know very little about the specific practices used in the P–12 classrooms where their students are placed."[41] Mentor teachers are expected to play a teacher educator role for the candidates they host while also carrying out the job of full-time classroom teacher, most without receiving the support and resources they need to provide truly high-quality mentoring. Teacher candidates and mentor teachers are often left to their own devices to determine what the "daily business" of the field experience will look like. In many cases, little supervision is provided, and those providing it are not faculty but others brought on to play this supervisory role, who therefore may have little real connection or standing within the teacher preparation programs.[42]

For foundational math, this misalignment between pedagogy and philosophy in preparation programs and fieldwork sites may be more pronounced given the progression of current views of math as conceptual rather than procedural. In cases where preparation programs are guiding candidates to teach math in more authentic ways, our Brain Trust notes candidates are often placed with mentor teachers in schools or districts that still view math as largely procedural and have a strong focus on test scores. In these cases, candidates are unlikely to see authentic instructional strategies modeled or be rewarded for demonstrating them. Harkening back to our catalysts, the extent to which instructors, in this case mentor teachers in field sites, model such instructional strategies greatly impacts candidates' learning of those approaches and ability to apply them in their own classrooms. Here again, we see a connection to the concept of fractals. Misalignment between those responsible for preparing teachers and those who employ teachers is reflected a level deeper as misalignment within preparation programs and inside of schools.

This is well-trodden territory, and despite general acknowledgement of the challenge and its implications for teacher candidates, significant change has not been seen in recent years across preparation programs.[43] The research undertaken for this report did not uncover why this is the case, but one reason could relate to organizational change management. It is no surprise that changing the culture and practices of any organization is difficult, but it is fairly common knowledge that universities, where many preparation programs are housed, face a particularly deep challenge when it comes to internal change. Furthermore, a long-standing belief that not everyone needs to know math, whether they be aspiring teachers or elementary-age students (discussed later in this report), could further the resistance to change. Why take the time to change program requirements if those who are naturally good at math will excel eventually anyway?

Many preparation programs are taking innovative steps to improve the experience for teacher candidates. One university working to bridge the divide between the education department and STEM departments to create higher-quality and more authentic course offerings and tools for teachers is California State University East Bay. The education and STEM departments at Michigan State University have also created a partnership to avoid the problems associated with operating in silos. Similarly, Rider University has worked extensively to design its teacher preparation program in a way that addresses the multiple challenges presented thus far, including fostering faculty modeling of instructional strategies, providing a balance of classroom learning and supervised field experience, developing a new math course sequence as a collaboration between the math department and school of education that ensures candidates receive sufficient and aligned math content and pedagogical instruction, and continually collecting and reflecting on data to refine their program. More information on Rider's program can be found in the spotlight later in this section.

HOW YOU CAN TAKE ACTION

- **Education faculty and math-content faculty** (with contribution and support from their department chairs) can collaborate to create or revise a sequence of courses that both covers the math content in depth and aligns to state learning standards and the expectations of elementary math instruction — which should lead to greater coherence across coursework and increased alignment among university departments. Read the spotlight on Rider University for an example of how faculty collaboration can improve how aspiring teachers are prepared.

- **Deans, department chairs, or other teacher-preparation program leadership** can revise the content of their coursework to help pre-service teachers develop an understanding of the coherence of mathematics concepts across the Common Core standards, especially in areas where students often struggle. Learn more about the connections between standards through The Coherence Map, a tool developed by Student Achievement Partners' Achieve the Core, and supporting blog "Creating a Coherent Math Curriculum".

- **State departments of education** can talk with preparation programs, schools, and teachers through interviews, listening tours, surveys, and other methods to gather more information about what might be smarter requirements for elementary teacher coursework and licensure.

CALIFORNIA STATE UNIVERSITY EAST BAY

California State University East Bay (CSUEB), serving the most racially diverse student body in the nation, established the Institute for STEM Education in 2011 with the mission of providing quality STEM education for all, providing education and opportunity to students throughout the region and meeting the hiring needs of employers in the STEM industries that drive California's economy. The Institute accomplishes its mission with a Collective Impact approach, bringing together cross-disciplinary resources both on campus and throughout the community, united by the shared goal of STEM education equity for all, from cradle to career.

In the past decade, faculty from CSUEB's Colleges of Science and Education have forged new collaborations aimed at developing a powerful understanding of effective STEM pedagogy PK–12, with a particular focus on reaching underserved communities. Funded primarily by the National Science Foundation and the California Department of Education, faculty have secured a series of grants to investigate current research about preparing pre-service and in-service teachers and exploring the most effective strategies to impact teacher STEM content knowledge and pedagogical content knowledge. Faculty who are content experts in chemistry, geology, math, computer science, and other STEM disciplines work with education faculty, with their deep knowledge of research and practices to prepare effective educators. As a result, beginning teachers are already prepared, for example, with a thorough understanding of the Next Generation Science Standards — from the perspective of a working scientist.

One example of this work is the Next Gen ASET Project, through which CSUEB has been leading a Networked Improvement Community of Education and STEM faculty from 10 institutions to develop a tool set enabling educators K–16 to master NGSS standards and build continuously improving team expertise. The toolkits that have been developed help educators unpack the three-dimensionality and interdisciplinary nature of the NGSS. They currently consist of a 3D map, which provides a conceptual framework of NGSS, and a set of Science and Engineering Practice Tools. This work recently received renewed funding from NSF and is expanding its reach.

ACTIONS I WILL TAKE...

FIRST STEPS TO GET THERE...

- [ ] ....
- [ ] ....
- [ ] ....

SOURCES

[34] Grade ranges covered by multiple subject credentials vary across states.

[35] Interview with Bruce Simon

[36] National Council on Teacher Quality (2017). State Teacher Policy Yearbook. Washington, DC: Author.

[37] Putman, H., & Walsh, K. (2019). A Fair Chance: Simple steps to strengthen and diversify the teacher workforce. National Council on Teacher Quality: Washington, DC.

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[42] Zeichner, K. (2010). Rethinking the connections between campus courses and field experiences in college- and university-based teacher education. Journal of Teacher Education, 61(1-2), 89-99.

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RIDER UNIVERSITY

For readers who may not be familiar with your organization and work, please provide a brief description of your organization.

The Rider University College of Education and Human Services (CEHS) prepares undergraduate and graduate students for professional careers in education, organizations, and agencies in the diverse American society. CEHS fosters committed, knowledgeable, reflective professionals through carefully developed, expertly taught programs for our graduate and undergraduate students. To this end, coursework and field experiences offer multiple opportunities for beginning and experienced teachers and other school personnel-in-training to learn new skills while strengthening existing ones, to build habits of professional thought that enhance practice, to seek and understand the theoretical underpinnings of such practice, and to apply new learning.

We promote continuous growth in our students by providing an environment in which it is safe to experiment, take risks, and make mistakes without sacrificing professional or academic rigor. Our goal is to foster this growth by faculty modeling of desirable behaviors; by providing a balance of classroom learning and supervised field experiences; by providing opportunities for ongoing independent and supported reflection on practice; and by encouraging novice and experienced educators to develop attitudes and behaviors that will support their professional growth. Through this process, we develop in our students the behaviors of committed teachers, school and organizational leaders, counselors, and school psychologists — the sound knowledge base which informs expert practice and the habits of reflection, which encourage professional growth, all leading to the development of the qualities of professionals.

How is your organization working to improve foundational math?

CEHS's efforts to redesign our teacher preparation program has served to propel us forward. Through developing a new nine-credit math course sequence as a collaboration between the math department and CEHS, while continually collecting and reflecting on data to refine our program, we have ensured that candidates receive sufficient and aligned math content and pedagogical instruction, as well as a balance of classroom learning and supervised field experiences. We have also enabled faculty from both departments to engage in collaborative work that supports their own professional learning and effectiveness as teacher educators.

All of CEHS's courses endeavor to increase expectations of candidates in the area of pedagogical content knowledge. In regularly scheduled faculty data retreats, advisory board meetings, and department meetings, faculty and K–12 collaborators pinpoint areas in which candidates tend to fall short of expectations with regard to general content knowledge. This helps CEHS target specific program changes, such as foundational mathematics knowledge. These reflective conversations, along with analysis of Praxis Core results, led CEHS professors to create a nine-credit math sequence. The sequence of courses was created through a collaboration between CEHS faculty, mathematics professors, and the mathematics department chair, and is aligned with New Jersey Student Learning Standards. The three-course sequence prepares education majors to teach students in elementary schools. College-level content is delivered using pedagogy appropriate for teacher candidates. The courses focus on effective instruction, developing essential understanding of concepts, strategies for formative assessment, and integrating mathematics practices.

The sequence is taught by mathematics faculty with K–12 experience, a component CEHS finds critical to ensuring that teaching faculty have the expertise needed to teach elementary math candidates. Additionally, each semester, the performance of candidates in the courses is reviewed. As a result of reviews of early implementation of the sequence, in summer 2017, the courses were further revised by a team of mathematics and mathematics education faculty members. A three-credit mathematics methods course was added to the education course sequence. It includes a half-day of classroom instruction and a full day of field experience. The field experience is mentored by the mathematics methods professor and the cooperating teacher. This enables the candidate to gain mathematics teaching experience in a setting that is aligned to what they are learning in their preparation courses.

What is core to your work? What elements are critical to its success?

One important element of our system is assessment for continuous improvement. We believe that assessment is a vehicle for educational improvement for CEHS candidates and those we serve. With benchmarks set by our institution's mission, our conceptual framework, professional standards, and our program goals, we are able to compare performance with intent, thus providing opportunities for advancement. Our approach to assessment for continuous improvement is based on the following beliefs:

- Focusing on learner outcomes provides a focus and relevance to assessment. Our conceptual framework, standards, and researched best practices form the foundation of what and how we teach, but it is the end goal of increased learner knowledge and skills that brings meaning to the process.
- Assessment using multiple measures across time (key transition points) provides detailed guidance toward improvement of programs and services.
- Data supports continuous growth and improvement. It should be systematically gathered, analyzed, and shared at multiple levels.
- Common assessments, along with program specific assessments, provide essential information about the success and needs of our programs and candidates.
- Including multiple and diverse voices in the assessment cycle is critical to consider all that the data reveals, both strengths and opportunities for improvement, in our effort to improve CEHS, our programs, and candidates.

How do you know this is working? What results have you seen?

First, we look to rates of candidates passing the Praxis exams as a key indicator of the success of our math sequence. After implementing the sequence, we have seen 100 percent of candidates achieve a passing score on the Praxis Core mathematics test and a 100 percent passing rate on the mathematics test, which is part of the Multiple Subjects Praxis II exam for elementary candidates.

Additionally, we use multiple assessment and evaluation instruments to manage and improve our work, collecting data from multiple stakeholders at multiple points in time. The quality and effectiveness of academic programs are measured through data aggregated from key assessments, state licensure tests, focus groups, and New Jersey Department of Education data reports. Course evaluations, faculty annual reports, and the results of faculty self-reflection surveys provide information on faculty performance and the direction for professional development. Aggregated data from candidate exit surveys, alumni, and employer surveys offer insight into our operations and resources such as advisement, technology, and library resources. The dean and the dean's cabinet meet regularly to review governance and budget issues.

Procedures are in place to allow for continuous evaluation and refinement of the programs and to ensure that appropriate stakeholders are involved in program evaluation and improvement. The Steering Committee (dean, associate dean, assistant dean, academic coordinator, the director of the Office of Field Placement, department chairs, career services specialist), the PK–12 Advisory Board, the Clinical Practice Advisory Board, and CEHS faculty review data on a regular and systematic basis. Biannual retreats are mechanisms for analysis, discussion, and formulating plans and recommendations for changes based on data reviewed. In addition, focus groups with candidates are utilized to evaluate and improve programs.

As you look to the future, where are you looking to improve or expand to make a bigger impact?

We continue to address areas for improvement and growth identified by our assessment system. One example is a series of mentoring videos for new teachers that we have developed. These eight-minute videos are conversations that take place between a novice teacher, experienced teacher, and faculty member. After viewing the video, questions are posed. These questions are used to guide mentoring conversations. A log accompanies the video so that the candidate can record her/his thoughts. We initiated this project to address the great need of providing good mentoring for novice teachers. Three mathematics mentoring videos have been produced. We will seek funding to grow this project.

About Spotlights

This research identified several organizations and models currently working to better equip elementary teachers to enable authentic and joyful math learning for all students. While these spotlights are at different points in their development and implementation, we believe all are promising places for the field to learn from when considering how to make progress on foundational math proficiency. 100Kin10 compiled these spotlights by inviting organizations to share core elements of their foundational math work through an interview-style questionnaire.

03

PROFESSIONAL GROWTH AND INSTRUCTIONAL SUPPORT

How might we enable school and district leaders to provide instructional leadership in mathematics and to support teachers with professional growth opportunities, curriculum, and other resources to continue growing in math content knowledge and pedagogy?

RESEARCH HAS INCREASINGLY SHOWN the strong positive relationship between teachers' continued learning and development and overall school quality, teaching practice, and student achievement.[44,45,46] While it is the responsibility of preparation programs to ensure their graduates have the skills and knowledge to lead a classroom effectively, researchers and our Brain Trust point to a need to continue shifting the field's mindset to acknowledge the importance of teachers' ongoing learning and evolution throughout their careers via regular and high-quality opportunities for learning, reflection, mentoring, and in-the-moment support.[47] As Kutaka et al. note, "The prevailing assumption that teachers learn what they need to know before they enter the classroom has been dispelled, and [professional development] has been recognized as an avenue to school improvement."[48] Along with opportunities for ongoing learning, teachers also require high-quality curriculum and other instruc-tional resources to support their efforts to deliver authentic math instruction.

However, many elementary teachers do not receive professional growth opportunities, curricula, and other resources specifically focused on growing their math content and pedagogical knowledge.

WHAT CAUSES THIS PERSISTING ISSUE?

01 School districts largely do not prioritize professional development opportunities for elementary teachers in STEM fields when making decisions around the allocation of resources and teacher time for professional development.

02 Many school leaders, often the gatekeepers for teachers' professional learning experiences, similarly do not prioritize math professional development for elementary teachers and may not have the foundational math content knowledge necessary to effectively direct these aspects of teacher professional learning.

03 There is a dearth of evidence about effective math professional development programs, leaving schools and districts responsible for using their own judgments about what activities and resources to select.

04 Math curricula in use may not be aligned to or allow for authentic approaches or instructional practices.

First, school districts largely do not prioritize professional development opportunities for elementary teachers in STEM fields when making decisions around the allocation of resources and teacher time for professional development. 70 percent of elementary teachers report spending 15 or fewer hours *total* over the last three years on mathematics-focused professional development, and less than half (46 percent) had received feedback about their math teaching from a mentor or coach in the last three years.[49] This last finding is not surprising, given data showing districts employ significantly fewer school- or district-based math coaches or specialists for elementary teachers, particularly as compared to the number available in English language arts.[50] Our Brain Trust and interviewees described the great emphasis in recent decades placed on literacy education throughout the PK–12 field and society more broadly, often to the detriment of math education. These larger beliefs filter down to the relative deprioritization of math professional learning opportunities by many districts; as is discussed later in the report, we suspect that this could be a reason for the lack of attention given to meaningful math-focused professional learning for elementary teachers.

In today's context of more rigorous standards and an increasingly conceptual view of math, it is even more important that teachers receive ongoing, high-quality professional learning opportunities to build and continually improve their understanding of math content and their ability to deliver high-quality authentic instruction. Darling-Hammond et al. describe this connection by saying, "Sophisticated forms of teaching are needed to develop 21st-century student competencies, such as deep mastery of challenging content, critical thinking, complex problem-solving, effective communication and collaboration, and self-direction. In turn, opportunities are needed for teachers to learn and refine the pedagogies required to teach these skills."[51] Specific to math, the content and mathematical practices defined by the Common Core State Standards and other similar rigorous standards require significant changes in math teachers' instructional practices in order to effectively implement the standards in their classroom. Additional support is needed on the part of many teachers to understand and implement these shifts.[52] Notably, there has been agreement among researchers about a set of core aspects of professional development that are associated with teacher and student learning, such as focusing on subject-matter content and how students learn that content, providing opportunities for teachers to engage in active learning, being of sufficient duration, and including opportunities for teachers to receive feedback and reflect on their practice and learning.[53,54] (See our "Teachers at Work" report for a more detailed description of the components of quality professional development.)

Second, looking beyond the role of school districts in allocating resources and time for math-focused professional learning opportunities for elementary teachers, school leaders also play a critical role in supporting teachers' ongoing professional growth. (Once again, we see an issue present itself at multiple scales across the system, here at both the district leadership and the school leaders levels.) Research shows that in large part, school leaders are the gatekeepers of professional development opportunities for teachers within their schools. They often control the form and function of professional development, and given their knowledge of the school community and context and of individualized teacher and student needs, they are uniquely positioned to influence the timing, content, pedagogy, and delivery of teacher learning opportunities.[55] Yet many school leaders do not have the foundational math content knowledge necessary to effectively direct these aspects of teacher professional learning. They likely learned the largely procedural view of math that dominated our schools in the recent past and may themselves need professional development to improve their own understanding of math as a conceptual and contextual subject, as well as what high-quality, authentic math instruction looks like aligned to these new understandings. Without this foundational knowledge, they may be less able to support their teachers by identifying areas of growth, providing quality feedback and coaching, or finding other appropriate sources of support to help shift and increase teachers' understandings and instructional capacity. Further, school leaders who are aware of their own deficiencies in these areas may have negative feelings about their instructional leadership abilities and avoid support in this area.[56,57] Read how Bank Street College of Education and The Center for Children and Technology at the Education Development Center (EDC) are working to improve the foundational math professional development offerings for teachers, coaches, and school leaders.

Third, when school leaders or districts do want to provide math-focused professional learning opportunities to teachers, they are faced with too little evidence about which programs are effective. The New Teacher Project's 2015 report "The mirage: Confronting the hard truth about our quest for teacher development" detailed the extent to which the current evidence base

BANK STREET COLLEGE OF EDUCATION AND EDC'S CENTER FOR CHILDREN AND TECHNOLOGY

Bank Street College of Education, located on the Upper West Side of Manhattan, views teachers and leaders as individuals who facilitate learning through carefully observing and meeting learners where they are in their learning process. Bank Street's commitment to STEM education is demonstrated through integrated and differentiated approaches to learning and teaching, where children and adults learn to understand themselves more deeply while making meaning of the world around them.

The Center for Children and Technology at the Education Development Center (EDC) began as the educational research and development division of Bank Street College. As one of the first education-technology research and development organizations, it has investigated the roles that technology can play in improving teaching and learning within children's classrooms, schools, and communities for more than 25 years.

Math for All, developed by Bank Street College of Education and EDC's Center for Children and Technology, is a professional learning program designed to assist schools and districts in improving the mathematics achievement of K–5 students who have diverse strengths and needs. Building on a neurodevelopmental framework for learning and utilizing a lesson-study approach, the program supports teams of general and special education teachers as they collaboratively plan and personalize mathematics lessons to support the achievement of all students. Math for All provides members of a school community with a shared framework and tools to plan and implement rigorous, student-centered instruction, and helps schools build a foundation for collaboration among general and special education teachers as they work to implement student-centered approaches for rigorous mathematics instruction.

The program differs from other commonly used approaches to professional learning in several important ways. It is designed to help enhance teachers' preparation to personalize instruction so they are able to better reach all students, and is designed for both general and special education teachers. Importantly, it also integrates learning about personalizing instruction within a specific academic content area (mathematics) and is more comprehensive and intensive than the professional learning teachers typically participate in to learn how to meet the needs of students with disabilities. Finally, Math for All engages teachers in collaborative lesson-planning to help to personalize their existing curriculum, rather than teaching them how to deliver a new curriculum.

Math for All is supported by an extensive evidence base. A recent large-scale randomized-controlled study found statistically significant positive effects of Math for All on students' mathematics achievement and on teachers' reports of preparedness and comfort in teaching diverse students (including students with disabilities). Math for All teachers were also rated by trained classroom observers as higher in emotional support, instructional support, classroom organization, and student engagement.[58] Teachers' testimonials illustrate these findings. After participation in Math for All, teachers report increased collaboration with other teachers on planning mathematics lessons, a growing recognition that diverse learners are more capable than they had initially thought, a better understanding of individual students' strengths, and an awareness of specific strategies that build on individual students' strengths to address their areas of weaknesses.

Bank Street's *Leadership in Mathematics Education Program* educates aspiring math leaders who will work as coaches, assistant principals, and principals to improve foundational math learning in schools by combining opportunities for coaches and school leaders to deepen their knowledge of mathematics and pedagogy while developing school leadership skills that support teachers' math instruction and students' math learning. The program is designed to meet the needs of educators with math knowledge and those looking to develop their math knowledge. Courses examine curriculum development, professional development, supervision,

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and research concepts and practices through a focus on mathematics.

The program also includes extensive supervised fieldwork under the close mentorship of a faculty advisor, usually in one's own school or educational setting. While in the program, aspiring leaders develop a deep understanding of mathematics and pedagogical practices that support student learning. They develop the skills and knowledge to support mathematics teachers, as well as all teachers, to provide quality learning experiences for their students. Particular attention is paid to issues of social justice, equity, racism, and biases, and the ways they are embedded in current educational structures and practices. Students develop the knowledge and skillset to engage in difficult and courageous conversation by surfacing personal mindsets, reflecting upon them, and addressing personal biases. Graduates laud the program for pushing their thinking about teaching mathematics as well as what it means to be a leader, building strong school communities and cultures while also engaging in groundbreaking conversations about race and equity.

Core to both Math for All and the Leadership in Mathematics Education Program are the beliefs that all children can be mathematicians and that teachers need to carefully observe children's math learning in order to support this process. Teaching practices need to respond to and follow learners' strengths and needs. Math coaches and school leaders need to provide teachers with models of how to develop a deep understanding of the mathematics goals of their lessons while matching instructional strategies to individual students. In addition, general education and special education teachers need time to share their observations of students as they collaborate and reflect on the possible instructional strategies. Finally, coaches and school leaders need to support teachers to be flexible when planning lessons and making decisions about classroom instruction.

on professional development activities is extraordinarily weak, even given the significant dollars spent nationally on professional development each year.[59] Research looking specifically at math-focused professional development found similar evidence gaps. Researchers in 2014 set out to answer the question "What does the causal research say are effective math professional development interventions for K–12 teachers aimed at improving student achievement?" by identifying and screening 643 research studies of math professional development approaches for grades K–12. Of these, only five studies met the evidence standards for the What Works Clearinghouse, and of those five, only two found positive effects on students' math proficiency. The authors summarized the implications of this, saying, "Thus, there is very limited causal evidence to guide districts and schools in selecting a math professional development approach or to support developers' claims about their approaches. The limited research on effectiveness means that schools and districts cannot use evidence of effectiveness alone to narrow their choice. Instead, they must use their best judgment until more causal evidence becomes available."[60] These findings are even more dismal as they address math professional development up through Grade 12, not just in the elementary grades.

While more research is certainly needed, filling the research gap is insufficient. Finding new ways to help those who most need the research find and use it is equally critical. A recent piece in *EdWeek* chronicles this disconnect between practitioners and research in explicit terms, describing a meeting between Institute of Education Sciences (IES) staff and teachers: "[I]t was fascinating to hear the teachers and administrators say, 'Someone should research this,' and the IES people are biting their tongues saying, 'We spent $50 million researching that! We have that answer!'" The article continues: "Fewer than half of the teachers had even heard of the What Works Clearinghouse, or the regional education laboratories that specialize in practical research on local issues," and quotes IES director Mark Schneider describing the difference between "completing and publishing education studies to ensuring their practical implications are communicated to the teachers and administrators who can use them."

Fourth, the math curricula selected by districts and schools also influence the extent to which elementary teachers are supported to teach in authentic ways. Our Brain Trust members note that many teachers face strong expectations to teach district or school-mandated curricula, with an eye toward test scores, especially in an era of high-stakes assessments. As noted in earlier sections, curricula and other district instructional materials and pacing guides may be unaligned to authentic approaches or practices. In these cases, if teachers had the desire to use such approaches, and had been introduced to these methods through their preparation program (as did Maria, our representative teacher described earlier in this report), the math curricula in place may limit the autonomy, flexibility, time, and support teachers have to integrate authentic teaching methods into their instruction, and to explore different ways of engaging students based on their observations of student learning.

Even given these challenges to elementary teachers receiving the professional growth opportunities and resources needed to increase their capacity regarding foundational math instruction, there are examples of school districts and universities actively working to improve their work in this area. Bank Street College of Education and EDC's Center for Children and Technology have developed programs for teachers, coaches, and school leaders. Hillsborough County Public Schools' math department created Math Leadership Academies as a way to provide targeted math-professional development for elementary teachers and leaders while elevating the need for this support. And Stanford University's Jo Boaler has created youcubed with the desire to educate and empower math teachers and transform the latest research on math into accessible and practical forms through a focus on growth mindsets and participatory learning.[61] As part of this work, Boaler and her team have developed a K–8 math curriculum series, Mindset Mathematics, designed to give students a joyful, creative, visual experience of math filled with growth mindset messages, as well as a set of tasks and videos available on the youcubed website, which are now used in 50 percent of U.S. schools.

HOW YOU CAN TAKE ACTION

- **Researchers** can increase the depth of the knowledge base on the core elements of effective professional development around elementary math instruction. Most importantly, researchers can work directly with school leaders, teachers, and professional development providers to ensure the findings are presented in ways that support the development and selection of high-quality professional development opportunities, such as those offered by the Public Education and Business Coalition (PEBC).

- **School leaders** can provide teachers with research-based math curricula that integrate authentic instructional practices, ensuring that teachers are spending time preparing for how they will engage all students in the material, rather than *what* they will teach. For example, many school districts, including Guilford County Schools in North Carolina, have seen significant gains in student learning by using Common Core–aligned Eureka Math.

- **School leaders and department chairs** can lead lesson studies and participate in them alongside their teachers. Lesson studies are inquiry cycles where teachers come together to ask and investigate a question of practice, plan for how they will address that question via a lesson, teach and observe the lesson, and then reflect on the lesson to identify what worked and where questions remain or emerge. Read how East Brooklyn Community High School has adopted the lesson study practice.

- **Preparation programs** can provide training and resources to mentor teachers, supporting them to reinforce core elements of the pre-service experience. This has the additional benefit of leadership development for the mentors as well as the opportunity to refine or bolster their own foundational math instruction.

YOUCUBED

Youcubed is a center at Stanford University dedicated to helping people develop positive relationships with mathematics and realize their potential as 21st-century mathematical thinkers. Under the leadership of Professor Jo Boaler, youcubed draws from neuroscience and mathematics education research to create accessible resources for teachers, designed by a team with real classroom experience. Through online courses, in-person professional learning, books, and a wide variety of free web-based tasks and videos, youcubed shows educators how to teach mathematics in ways that are creative, visually engaging, and inclusive. This approach, which incorporates growth mindset as an integral component of

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all aspects of mathematics learning, is known as Mindset Mathematics and has the power to transform classrooms and students' math experiences.

Specifically, Mindset Mathematics enables inquiry-based teaching by combining growth mindset messages with open, visual content and by encouraging classroom cultures that support collaboration and risk-taking. For elementary teachers, this approach is described in the Mindset Mathematics curriculum books for Grades 3–6 and in the many materials and videos on youcubed.org that are designed for younger students. The core elements of the curriculum are "low floor, high ceiling" tasks that help teachers guide students on an exploration of the big ideas in elementary mathematics through visualization, play, and investigation.

Evidence for the effectiveness of Mindset Mathematics is abundant and growing. A study of a yearlong network, in which fifth grade teachers across eight school districts took the online course "How to Learn Mathematics for Teachers" and used youcubed tasks in their classroom, showed that students of teachers who participated achieved at significantly higher levels on standardized mathematics tests at the end of the school year. The students also significantly shifted their mindset and appreciation of mathematics. The achievement boost particularly impacted girls, students that are English-language learners, and socioeconomically disadvantaged students. Similarly, in a randomized controlled trial of middle school students taking the online course "How to Learn Mathematics for Students," students who took the class significantly changed their mindsets and achieved at significantly higher levels than the control students on standardized mathematics tests a year later, and were significantly more engaged in their mathematics classes.[62]

ACTIONS I WILL TAKE...

FIRST STEPS TO GET THERE...

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- [ ] ......
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HILLSBOROUGH COUNTY PUBLIC SCHOOLS

For readers who may not be familiar with your organization and work, please provide a brief description of your organization.

Hillsborough County Public Schools is located in the Tampa Bay area, Florida. It is the eighth largest school district in the nation and has 147 elementary schools. The elementary math department is comprised of three people at the district level and six district coaches that spend most of their time at school sites, coaching teachers and site-based leaders. Our district currently faces two key challenges related to foundational math: supporting our teachers in building their content knowledge for teaching mathematics and finding ways to support more members of our community in an effort to educate them on the math standards, related instructional strategies (that may be very different from the procedural math they encountered as students), and effective ways to support their children's learning.

How is your organization working to improve foundational math?

During the 2018–2019 school year, the elementary math department led an initiative to support schools in shifting their mindset around the work that typically took place during teacher planning sessions. Traditionally, much of the time spent during planning sessions focused around notating which lessons and page numbers from a resource would be taught on which days, rather than exploring the meaning of standards, instructional implications, and strategies to push students' thinking forward.

Last year, approximately 60 of our 147 elementary schools had site-based mathematics coaches. About 50 percent of these coaches, however, were first-year coaches. There was an obvious, identified need to support the math coaches and teacher leaders in integrating professional development (PD) focused on building teachers' content knowledge for teaching within their planning sessions.

The elementary math department developed PD around this goal and called it the Math Leadership Academy, or MLA. The MLAs are two-hour PD sessions focused around grade-level standards that have been identified as either difficult to teach or challenging for our students to learn. The sessions were scheduled so that the concepts and skills covered were presented two to three weeks prior to those same topics occurring in the classroom with the students. Participants in the PD sessions were expected to return to their school and incorporate the activities within their grade-level planning sessions.

The two-hour PD sessions engaged participants in challenging tasks and questions that helped them to build a deeper understanding of the standards. Session facilitators incorporated coaching and support tools into each presentation, so that the participants felt confident and equipped to return to their school sites and lead a similar planning session with their grade-level team.

Administrators and leaders of mathematics at school sites were also encouraged to identify possible teacher leaders that would be interested in deepening their content knowledge for teaching mathematics and would be willing to share their new knowledge with fellow grade-level team members during planning sessions. Interested teachers submitted applications to attend the MLA sessions. Their application included a section for the principal's approval and a statement of support from the administrator that the teacher leader would have time to implement the planning session with their grade-level team.

What is core to your work? What are the one to three elements that are critical to its success?

The element that is most critical to the success of the MLAs is the inclusion and involvement of the site-based administrator. We took purposeful steps to involve the administration, such as:

- Requiring administrative approval of the candidate's application to join the Math Leadership Academy.
- Scheduling the sessions to begin at 2 p.m., even though students weren't dismissed until 1:50 p.m. This "forced" the teacher leader participants to talk with their principal about coverage for the last 15 to 20 minutes of the day. This alerted and reminded the administrator that their teacher was leaving to attend an MLA on that day (and to expect them to follow up with their team within the next few weeks). Additionally, it created a sense of higher value for the participant, sending the message that the MLA is important training and teachers need principal approval and classroom coverage to attend. We believe this encouraged both the administrator and teacher leader to make the most of this PD opportunity.
- Requiring the administrator verification that the planning session was indeed implemented with the grade-level team, following attendance at each MLA session

How do you know this is working? What results have you seen?

In the 2018–2019 school year, we facilitated four MLA sessions for each grade level. The sessions were attended by approximately 35 teacher leaders per grade level. The teacher leaders that attended the MLA sessions received inservice points towards recertification, but only after they submitted proof of implementing the planning session with their grade-level team back at their school site. Proof of implementation involved the participant completing a reflection form, having it signed by their administration, and sending us a digital copy for verification. We received over 100 verification reflection forms for the sessions facilitated during the 2018–2019 school year.

One of the goals of the MLA project was to create more interest in teachers taking on mathematics leadership roles in their school. One of the ways in which we can measure this is in the number of teachers going through the screening process to become a math coach. In previous years, we typically have between 10 to 15 candidates that complete applications and interview to become site-based math coaches. This year we had over 40 candidates, and many referenced their experience with the Math Leadership Academy as a motivator for them to take on more of a leadership role in mathematics.

As you look to the future, where are you planning to improve or expand to make a bigger impact?

One challenge our leadership academy

trainers experienced the first year of the project was responding to the varying levels of content knowledge with which the teacher leaders entered each session. The breadth of differentiation required due to the wide variability of teacher leaders' knowledge base often did not leave enough time to ensure that all participants left with the coaching tools and support they needed to return to their site and confidently facilitate their own grade-level planning session/training.

For next year, we are planning to incorporate some pre-session "homework" using a flipped classroom model. Participants will be sent a few links to media such as articles, videos, etc., providing them with basic background knowledge on the upcoming MLA topics. This will help to provide a foundational level of understanding for all participants prior to arriving at the MLA session.

Additionally, for the 2019–2020 school year, we have a goal to bring on 40 new teacher leaders per grade level for a total of 240. We have a target implementation rate for next year of 75 percent (participants who attended the MLA, implemented the planning session with their grade level team, and submitted the verification/reflection form).

About Spotlights

This research identified several organizations and models currently working to better equip elementary teachers to enable authentic and joyful math learning for all students. While these spotlights are at different points in their development and implementation, we believe all are promising places for the field to learn from when considering how to make progress on foundational math proficiency. 100Kin10 compiled these spotlights by inviting organizations to share core elements of their foundational math work through an interview-style questionnaire.

UCLA MATHEMATICS PROJECT AND LOS ANGELES UNIFIED SCHOOL DISTRICT

For readers who may not be familiar with your organization and work, please provide a brief description of your organization.

The University of California, Los Angeles, Mathematics Project (UCLAMP), a California Subject Matter Project, is housed in UCLA's Center X and partners with Los Angeles Basin districts, schools, and teachers to provide rich and transformative mathematical experiences to meet the needs of each student. UCLAMP has been providing Cognitively Guided Instruction (CGI) professional development for many years. CGI is a well-researched approach that meets Every Student Succeeds Act standards and engages teachers in the details of children's mathematical thinking, using teachers' strengths to make sense of and support students to build on their mathematical thinking. This work is a partnership with the Los Angeles Unified School District, where we are engaged with district staff, as well as early childhood and elementary mathematics schools and centers. LAUSD currently includes 449 elementary schools and 19 primary centers. There are 319,000 elementary school students: 73 percent Latinx, 10 percent white, and 8 percent African American.

How is your organization working to improve foundational math?

UCLAMP's approach involves a focused and consistent method of providing CGI professional development (PD) involving teachers, school leaders, and teacher leaders. In Year 1 of participation, schools have eight buy-back two-hour sessions after early release. Across all schools, each session has a focus, but the PD itself is tailored to the needs of the school by the CGI professional developer. In addition, the professional developer spends the morning in the school providing in-the-moment support, learning about the school community, and seeing how to take ideas and examples back to the afternoon PD session. In Year 2 of participation, schools also have eight PD and site days, with consistent focus areas across schools that build on the work completed in Year 1. In Year 3, the schools have fewer PD days and are therefore supported by UCLAMP through the use of Teacher Learning Protocols to self-lead the PD sessions.

Notably, we are currently working to support over 100 teacher leaders from across LAUSD schools, with more growth expected, through providing extra professional development and enabling them to serve as apprentices to eventually become professional development and site leaders.

LAUSD staff have played a central role in creating a range of learning opportunities for teachers, both in the current partner schools and in the schools not yet participating. LAUSD has created online CGI modules that teachers are paid to complete. They have also created classroom videos from across grades and schools which are available for teachers to view, and have supported summer institute opportunities for teachers to receive more advanced CGI training. These are open first to partner schools and then to all schools in LAUSD. This year, UCLAMP provided training via summer institutes for over 2,500 LAUSD teachers and administrators.

Finally, because UCLA also prepares approximately 50 elementary teachers each year, we are integrating the same mathematical and social justice focus into UCLA's Teacher Education Program. Upon graduating, our teacher candidates are often hired in the 120 partner schools, coming in with knowledge, skills, and mindsets that are consistent with the goals of the partnership work.

What is core to your work? What are the one to three elements that are critical to its success?

Core to the work is our focus, having multiple entry points, engaging in school-based partnerships, ensuring the work is ongoing and has a clear commitment from the district. First is the development of children's mathematical thinking, both what research offers about how children make sense of mathematics and how their thinking develops. CGI offers a framework for helping educators become generative in their understanding of children's thinking, and the focus serves to change the narrative from what children cannot do to what children can do. It is an asset-based approach that acknowledges that all children have mathematical ideas to offer and build from.

Second, we provide multiple entry points to allow schools to choose when and how to enter the work, offering two different pathways for the focus of the school-based professional development, as well as offering online and summer institute opportunities. These additional supports were taken up in different ways by schools and individual teachers.

Our school-based approach meant that all teachers, and often all staff, participated in the professional development sessions, with the professional developer spending the morning in the school providing in-the-moment support. The school-based approach also included working with principals to support their learning and work. The principals not only attended the school-based PD sessions, but were also invited to join virtual calls following the PD, where we debriefed the PD, how their teachers were making sense of the PD, and how they were going to support them in between the PD sessions. Principals were also invited to three Saturday PD sessions only for principals and their teacher leaders.

Additionally, balancing a consistent yet personalized focus of the PD across schools is an important component of our school-based approach, serving to build common knowledge and language while also addressing individual schools' needs. For example, if all schools are working on eliciting students' mathematical thinking as the focus of a particular session (yet with some level of differentiation in the specific nature of the content), conversations can occur across schools and in our principal sessions about that idea. This approach allows for the development of a common language and a shared effort, while also providing a level of personalization to schools.

Finally, LAUSD's commitment and plan for a steady and slow rollout, with multiple years of tiered support, has ensured the work will be ongoing. We piloted in 12 schools, then moved to 60, then to 120, and now planning for 210, with participating schools continuing their work over multiple years, each with a different level and content for PD sessions. As we began the work with the 60 schools, UCLAMP and LAUSD together identified teacher leaders — teachers in the schools who had well-developed understanding and practice in CGI — to take on the professional development work at a different site, with support from UCLAMP. We now have 100 LAUSD teacher leaders who grow the internal capacity to continue the work.

As you look to the future, where are you planning to improve or expand to make a bigger impact?

Our forward-looking view sees several key areas for expansion or improvement. First, we want to continue to improve upon our work with principals. For example, we recently tried out microteaching, or rehearsal with principals, and saw tremendous learning, and similarly want to provide more support for principals to think about assessment and parent engagement.

We are also engaged in planning how to continue to meet the CGI professional learning needs of schools as they move into their third and fourth year, where the administrators and teachers themselves are the leaders of the work and have piloted an approach to support principals and teacher leaders in taking this on at their school site.

Overall, the most significant challenge is maintaining the work in a large, complex district with many diverse needs. Thanks to the great partnership with LAUSD and district leadership, we are expanding our engagement to include departments outside of mathematics, such as special education, dual language learning, and early childhood, that will be critical partners to our overall success.

About Spotlights

This research identified several organizations and models currently working to better equip elementary teachers to enable authentic and joyful math learning for all students. While these spotlights are at different points in their development and im-

plementation, we believe all are promising places for the field to learn from when considering how to make progress on foundational math proficiency. 100Kin10 compiled these spotlights by inviting organizations to share core elements of their foundational math work through an interview-style questionnaire.

04

ELEMENTARY MATH SPECIALIZATION

How might we increase the number of elementary math specialist roles in schools and the training and support for these roles from districts, states, and preparation programs?

FOR THE PAST SEVERAL DECADES, the call for specialization in elementary math instruction has grown. Organizations like the National Council of Teachers of Mathematics, the National Mathematics Advisory Panel, and the Association of Mathematics Teacher Educators have all pointed to the need to increase the availability of these roles, both in terms of the number of states offering certifications for specializing in elementary math and the availability of full-time roles within schools, districts, and states for those with the requisite training. Further, we have heard from our 100Kin10 Teacher Forum that having a specialist in the building is one of the most valuable supports their school could offer to teachers who are not yet comfortable with more authentic methods of teaching STEM.

The 100Kin10 Teacher Forum is made up of leading STEM teachers who help 100Kin10 keep a pulse on what's happening on the ground by pointing to real-time insights from classrooms and schools across America.

The rationale supporting specialist roles in elementary math focuses on the understanding that teaching foundational mathematics is complex, particularly within the context of standards-based instruction and an evolving understanding of math that is conceptual in comparison to the largely computational notion of math that defined math education for previous generations. The math pedagogical content knowledge required of teachers to effectively deliver this instruction is significant[63] and, as our Brain Trust noted, varies across the PK–5 continuum. In other words, the content knowledge and instructional practices most appropriate for onboarding students to mathematics concepts in kindergarten and first grade are quite different from those required when teaching concepts such as fractions and decimals in the later elementary grades.[64,65,66]

Even with a clear rationale for these roles, elementary math specialist roles are still uncommon.

WHAT CAUSES THIS PERSISTING ISSUE?

01 Longstanding perceptions exist that elementary teachers should be generalists, and ingrained practices and structures reinforce this belief.

02 There are limited existing school or district roles available to teachers with this specialization, given the relative deprioritization of math and fewer resources that could support these professionals.

03 Credentialing pathways for elementary math specialists do not exist in the majority of states, even given the strong rationale supporting them.

04 Elementary school staffing models largely do not include opportunities for teachers to specialize in math instruction, particularly in the earlier grades.

05 Few teachers take advantage of the opportunity to become an elementary math specialist when the opportunity does exist because they lack the necessary knowledge and skills.

First, elementary teachers in the United States by and large are generalists and have been for decades. The prevailing perception of how elementary students should be organized for learning revolves around a homeroom classroom, where students receive the majority of instruction from one teacher. That single teacher is expected to teach students with wide-ranging abilities, both in whole group and small group formats, in multiple subjects on any given day. More specifically, as noted earlier, elementary teachers are expected to be experts not only in providing instruction across the full spectrum of math content from grades PK–5, but similarly across all relevant content for all other subject areas across this grade span. Given these long-standing beliefs, many experts are questioning the continued expectation by the PK–12 field that elementary teachers can and should be good at teaching all subjects, noting that it may be unreasonable to expect one individual to be expert in all content and skills across the PK–5 continuum and similarly unreasonable to expect preparation programs to be able to effectively train candidates for this breadth and depth of knowledge. As far back as 1989, in *Everybody Counts: A Report to the Nation on the Future of Mathematics Education*, the National Research Council noted, "The United States is one of the few countries in the world that continues to pretend — despite substantial evidence to the contrary — that elementary school teachers are able to teach all subjects equally well. It is time that we identify a cadre of teachers with special interests in mathematics and science who would be well prepared to teach young children both mathematics and science in an integrated, discovery-based environment."[67] Yet the perception of elementary teachers as generalists persists.

A second factor limiting the number of specialist roles is that many teachers do not have access to credentialing pathways for elementary math specialists within their state. As of 2017, only 20 states offered certification or credentials for elementary math specialists, as compared to nearly all states offering credentials for reading specialists.[68] While that represented a sharp increase from the nine states offering these credentials in 2010, it nonetheless means teachers residing in 60 percent of states cannot obtain this training and specialist credential.[69] Notably, additional states are working to create these opportunities through their licensure options. Read the spotlight at the end of this section to learn about the work being done in Illinois to create an Elementary Math Specialist Program and related licensure pathway through a partnership between CME Group Foundation, Chicago Public Schools, and three universities: DePaul University, University of Chicago, and University of Illinois at Chicago.

Third, districts often do not have existing roles for elementary math specialists to fill either at the school or district level, or offer very limited placements for teachers with specialist knowledge and credentials. As noted above, whereas in many cases districts assign each school a reading specialist, math specialist roles are generally rarer and under-resourced. Examples are plenty of school districts assigning one district-level elementary math specialist to cover 10 or more schools, as compared to reading specialists assigned to just one school. This may present a challenge for the field if the supply of credentialed specialists increases, as indicated by the growing number of states offering this pathway, but the demand on the part of districts for these professionals and new roles they can fill does not similarly increase. There is hope in this regard as the Chicago example illustrates, where school districts across the state have expressed increasing interest in this role and certification pathway, adding support to the partners' application to the state to create the new credential.

Fourth is a related point: Elementary school staffing models largely do not include opportunities for teachers to specialize in math instruction, particularly in the earlier grades. Researchers recommend that elementary schools consider math specialization similar to the ways that other classes, such as music, art, and physical education, are taught by one teacher within a building with specialized expertise and training in the subject.[70,71] While school staffing models as often designed can make it challenging to create math specialist roles, there are multiple examples of districts successfully designing staffing models and school schedules that specifically provide for elementary math specialists.

For example, Powhatan County School District in Virginia has recently created full-time math coach roles for each elementary school. The district also employs two STEM coaches that share responsibility for the three elementary schools, an additional math specialist serving grades K–12, and a science and STEM specialist serving grades K–12.

Fifth, our Brain Trust also notes that in some cases, even when specialist certifications do exist, they require a level of prior math content coursework that many elementary teachers do not possess, therefore limiting the extent to which elementary teachers are eligible for the specialist certification without first taking a significant number of higher-level math courses. This

POWHATAN COUNTY PUBLIC SCHOOLS

Powhatan County Public Schools (PCPS) is in the rural community of Powhatan, Virginia, with a population of approximately 29,000. It has three elementary schools (K–5), a middle school (6–8), and a high school (9–12). All are Title I schools. PCPS is committed to investing in human resources. Each elementary school has a full-time math coach and two STEM coaches share responsibility for the three elementary schools. A math specialist serves K–12, along with a science and STEM specialist. Having a full-time math coach in each building has allowed for significantly more modeling of effective instruction, as well as professional development within the school day as coaches model lessons, gather resources for teachers and set up activities, co-teach as teachers learn new skills, and meet with teachers biweekly during a planning time.

The math coaches, who all hold math specialist degrees and were classroom teachers prior to their role as coaches, provide weekly professional development in the areas of student communication, training in the appropriate use of manipulatives, differentiation of the math curriculum, creating math workstations, and high-yield routines. Additionally, the STEM coaches work with the math coaches to embed math applications within their STEM lessons, serving to integrate the curriculum and make learning more meaningful and authentic to the students. The region also holds an annual math mini-conference, where teachers provide workshop sessions for other teachers in an effort to help give them a clearer understanding of what they are seeing in their math classrooms and how they can support effective mathematics in their buildings.

Providing these coach and specialist roles is indeed a financial investment, but one that PCPS feels is very worthwhile. The evolution of these roles occurred over time, starting with school-based lead teachers or specialists with sporadic leave time that allowed them to model lessons or co-teach to share their knowledge and strategies with others. As the impact of these experts became clear, the district prioritized finding funding to support them, even utilizing creative strategies such as not purchasing print textbooks and instead utilizing digital resources, or better organizing and using existing resources to realize additional cost savings. The investments in people, while maximizing material resource effectiveness, has had a real impact on students and teachers. Classroom observations across the three elementary schools show students engaged in meaningful discovery in math, talking about math, and discussing their reasoning. Teachers move about the room, asking strategic questions and engaging the learners. Students are effectively using manipulatives to really understand mathematical concepts. They are involved in math work stations which spiral the curriculum. In lessons outside of the math block, students can also be seen applying these skills through engineering challenges and in science activities. Teachers have also seen improvement in early number knowledge among students in grades K–2.

is not surprising, given research shared earlier about the limited number of math content courses required of elementary teachers as part of their preparation program.

It is important to note that in some cases where elementary math specialist roles exist, their current design may not maximize their potential for several reasons. Studies have shown that specialists' job responsibilities may not be well-aligned with their perceptions of teacher needs and how to best support them. In one study, exploring the perceptions of elementary math coaches (one version of an elementary math specialist) about their current role as compared to what they believe their role should entail, researchers found several areas where existing responsibilities did not align with those deemed to be important for the role by coaches. Actions such as leading study groups, evaluating educational structures and policies that affect students' equitable access to high-quality math instruction, and using professional resources to inform critical issues related to math teaching and learning were areas with the largest discrepancy, meaning coaches saw these as important aspects of what they should be doing to support math instruction in their schools, yet they were not part of their job responsibilities.[72] Further, specialists may be asked to focus on teaching a particular district or school initiative or curriculum, rather than working directly with students or supporting teachers around more fundamental needs, such as content understanding and mastering pedagogical strategies. As our Brain Trust noted, when this occurs, it greatly limits the ability of the early-math specialist to address the gaps in math pedagogical content knowledge — and confidence — that are prevalent among elementary teachers.

HOW YOU CAN TAKE ACTION

- **Deans, department chairs, or other teacher-preparation program leadership,** in partnership with local districts, can experiment with elementary math specialization programs that build on existing certification or master's programs. Read the spotlight on CME Group Foundation and Chicago Public Schools for an example of how several Chicago-based universities piloted and are now expanding on a specialist program.

- **School boards, other district-level leaders with budgetary oversight, or in some cases, school leaders** can allocate resources to bring on coaches focused on supporting foundational math instruction, removing the expectation that each teacher be an expert in teaching math. Powhatan County School District is an example of how one small rural district achieved this.

- **Teachers and families** can talk to their state representatives or state Department of Education about the importance of developing an elementary math specialist credential.

ACTIONS I WILL TAKE...

FIRST STEPS TO GET THERE...

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CME GROUP FOUNDATION AND CHICAGO PUBLIC SCHOOLS

For readers who may not be familiar with your organization and work, please provide a brief description of your organization.

CME Group Foundation strives to empower future generations through education, equipping today's students to meet tomorrow's challenges. They will shape the future of the world's most important industries, including our own, so we give them the tools they need to achieve their full potential, including:

- Ensuring disadvantaged young children become proficient at math at the appropriate grade or developmental level
- Providing low-income K–12 students with computer science and financial education
- Using technology to personalize learning and improve outcomes for disadvantaged students
- Helping low-income students succeed in college and career

How is your organization working to improve foundational math?

The Early Math Education Initiative was launched in 2010 to help young children from low-income Illinois communities become proficient in math at the appropriate grade or developmental level. The initiative creates a timeline of best practices from birth through third grade to help teachers and caregivers provide the needed development. We encourage our grantees to collaborate with others to enhance learning and share best practices.

In 2017, CME Group Foundation partnered with Chicago Public Schools and three universities — DePaul University, University of Chicago, and University of Illinois–Chicago — for a pilot Elementary Math Specialist Program. The three universities worked collaboratively to draft course outlines focused on strengthening the mathematics content and pedagogical knowledge of elementary school teachers through university coursework and classroom teaching in high-need public schools. Forty-five CPS teachers recently completed the pilot program. Throughout the pilot, the universities and the CPS Office of Mathematics have continued to collaborate regularly to share learnings and plan for upcoming activities.

In 2019, the Foundation funded these four partners to expand the Elementary Math Specialist program in several ways. First, 45 additional teachers were funded to take the Elementary Math Specialist coursework offered by the universities. Additionally, a community of practice, in partnership with DePaul University, was created to provide targeted, job-embedded learning to teachers who participated in the pilot coursework. Participation was also expanded to include teachers from the Academy of Urban School Leadership (AUSL), and Governors State University joined to offer courses to teachers in a south suburban low-income district.

What is core to your work? What are the one to three elements that are critical to its success?

Critical to the success of CME Group Foundation's Early Math Initiative in general, and our Elementary Math Specialist program specifically, is the willingness of universities to partner with districts and early childhood providers to create and deliver professional development for early childhood and early elementary teachers. The universities have forged long-term relationships with the schools they serve as well as with each other in a noncompetitive manner. We believe committing to 10 years of support for our Early Math Initiative enabled our grantees to forge these long-term, deep partnerships.

How do you know this is working? What results have you seen?

Early data from the pilot indicates improvements in teachers' instructional practice, content knowledge, and confidence. Participants have also been very enthusiastic about attending the courses and taking what they've learned back to their schools. We see strong demand for the courses among teachers. Recently there were 60 applicants for 15 slots, causing a university partner to double the class. We continue to see strong partnership with CPS and alignment of the program with the district's broader human capital work. District leadership has been very supportive of the program and is including it in its new teacher-leader talent development initiative.

As you look to the future, where are you planning to improve or expand to make a bigger impact?

Moving from direct service to teachers to statewide policy work over the last two years is the next "edge" of our work. The Foundation recently funded University of Chicago to do an Elementary Math Specialist landscape scan. Our university partners requested the Illinois State Board of Education (ISBE) consider adding an Elementary Math Teacher and Elementary Math Specialist credential. The landscape scan will measure the need and demand for these credentials among all Illinois school districts to inform ISBE. We hope that ISBE approves these new credentials within the next year, causing districts to seek out and hire these specialists, as well as driving demand among teachers to gain this credential, knowing their districts desire and have created these roles.

About Spotlights

This research identified several organizations and models currently working to better equip elementary teachers to enable authentic and joyful math learning for all students. While these spotlights are at different points in their development and implementation, we believe all are promising places for the field to learn from when considering how to make progress on foundational math proficiency. 100Kin10 compiled these spotlights by inviting organizations to share core elements of their foundational math work through an interview-style questionnaire.

05

EMPOWERING AND SUPPORTIVE ENVIRONMENTS

How might we foster elementary school environments where teachers are empowered and supported to teach math (and to lead the teaching of math) in authentic and joyful ways?

AS IS THE CASE for all grades and subjects, the environment in which teachers work, the support they receive, and the knowledge, beliefs, and past experiences they bring with them to the schoolhouse, all influence their ability to teach in authentic and joyful ways. However, we know that elementary schools are often not places where teachers feel empowered and supported to teach math in authentic and joyful ways.

Work Environment Connection: When schools have a positive work environment, teachers thrive and continue to grow in their profession. As a result, their instruction improves and student learning soars. Read more about the importance of nurturing positive work environments for teachers in our "Teachers at Work" report.

WHAT CAUSES THIS PERSISTING ISSUE?

01 Many teachers and school leaders alike lack the conceptual math knowledge and skills, as well as confidence in their own math abilities, that are necessary for strong instruction, providing a rocky foundation for teachers in the classroom and for leaders tasked with helping to support their teachers.

02 High-stakes testing and the focus on math scores decreases the extent to which elementary schools are primed for joyful math teaching and learning.

03 Beginning teachers with the knowledge and desire to use inquiry-based approaches often enter schools with existing culture and expectations that do not align with these instructional approaches.

04 Math continues to be seen and taught as a distinct subject, rather than integrated with other subjects, connected to the real world, and relevant to students' everyday lives.

First, some elementary teachers' and leaders' have insufficient conceptual understanding and knowledge of math, which leads to anxiety about doing and teaching math. Sian Beilock, a nationally recognized cognitive scientist and the current president of Barnard College, has conducted extensive research on math anxiety and found that it causes people to struggle with even simple math problems. This can have long-lasting effects, as "math attitudes and anxiety predict math achievement, which in turn predicts attitudes and anxiety."[73] Beilock's research has also pointed to the particular consequences teachers' math anxiety has for girls, showing how it impacts who young girls believe can be good at math.[74] A 100Kin10 white paper, "Many elementary teachers have anxiety about teaching STEM subjects", supports the role of content knowledge in eroding confidence, noting that elementary teachers' lack of confidence in STEM is tied to "insufficient content knowledge (knowledge of STEM) and pedagogical content knowledge (knowledge of how to teach STEM), which makes it a challenge for them to move beyond teacher-directed rote teaching and learning of STEM content." Many of these feelings are associated with their own negative past experiences as math students. Teachers who experience this anxiety may have no one to turn to for support or help in their building, given, as noted above, the limited availability of math coaches or specialists at the elementary level.[75,76] This lack of confidence and content knowledge can translate to fear and discomfort in the classroom, making teachers reluctant to try more interactive instructional practices in math. In many cases, teachers' and leaders' limited skill set and discomfort are the result of how they experienced math as students and/or through their careers, as well as major shifts in the field in recent years about how we think about math and how best to teach it. Interestingly, these are the same shifts that have led to teacher preparation faculty being disconnected from what elementary math actually looks like in classrooms and schools. It seems as though there is ample room for individuals and institutions to catch up to what 21st-century math learning looks like and requires, as well as what it can enable young students to achieve.[77,78]

Alongside a lack of confidence and knowledge, a second factor impacting the extent to which elementary teachers feel empowered and supported to teach math in more authentic and joyful ways is the focus on high-stakes testing. Research shows that high-stakes testing has had a significant impact on curricular and pedagogical decisions, and in the case of math, it has led to a continued focus on lower-level skills as assessments continue to focus in large part on procedural knowledge.[79,80] Moreover, because a focus on test scores often leads to instruction that is most focused on memorization rather than deeper engagement with concepts, it further discourages teachers and leaders from addressing their own lack of confidence and skills with the subject matter. To further tease out the issue, what we most often test when it comes to student learning is what we can measure. However, what is easy to measure is often not what is most important for students to learn, the most engaging information, or a product of more authentic instruction. And in fact, the need for more accountability systems that promote teacher creativity is another of the highest-leverage catalysts on the Grand Challenges, which points both to the interconnection between the catalysts, their wide-ranging impact and potential for downstream impact across the system, and the importance of this particular finding.

Third, in some cases, beginning teachers do graduate from their preparation programs with the knowledge of how to teach meaningful and authentic math and see the importance of doing so. Yet when they enter a school environment where their leaders and/or peers do not have the confidence or skills to use authentic strategies, or where test scores are the primary goals, they often face resistance or doubt from their colleagues. They are encouraged to stick to the tried-and-true methods, and in some cases are required to use curricula or other instructional materials that are misaligned to the practices they have learned.[81] As a result, it can be hard for fresh ideas and new practices to permeate school communities.

Fourth, the perception that math is distinct and disconnected from other STEM and non-STEM fields contributes to many teachers and students not seeing math as authentically integrated into everyday life in a meaningful way. In many cases, math instruction is siloed and fails to make connections with other content areas or real-world application. High-stakes testing contributes to this challenge, as it encourages the continued segregation of math from other related subjects. As described earlier, we have come to understand that authentic instruction encompasses strategies that exemplify real math learning, such that students see how math concepts connect to each other, other STEM subjects, and the world at large. The introduction of math in ways that are authentic and connected to students' everyday lives and the world around them during these foundational years is critical to help drive positive feelings about math and a joyful curiosity around math learning in the classroom. Members of our Brain Trust describe how math is often still viewed as a distinct category of instruction, different from other disciplines, such as the arts and humanities, and even treated separately from other STEM fields such technology and engineering. This has been echoed by our 100Kin10 Teacher Forum. Math teachers in particular reported that math can feel removed from and even unwelcome in the STEM community. It can therefore be difficult for teachers to see how math can be connected to other disciplines, including STEM ones, and similarly difficult for students to see those important connections.

The 100Kin10 Teacher Forum is made up of leading STEM teachers who help 100Kin10 keep a pulse on what's happening on the ground by pointing to real-time insights from classrooms and schools across America.

While integrating math in authentic ways with other disciplines could help promote perceptions by teachers and students of its importance and applicability, research shows the work to integrate this content is challenging: "The process of integrating science, technology, engineering, and mathematics in authentic contexts can be as complex as the global challenges that demand a new generation of STEM experts. Educational researchers indicate that teachers struggle to make connections across the STEM disciplines. Consequently, students are often disinterested in science and math when they learn in an isolated and disjointed manner, missing connections to crosscutting concepts and real-world applications."[82]

Given the frequent disconnect between math and other STEM and non-STEM fields, the ongoing focus on high-stakes testing, and teachers' lack of confidence in math and largely procedural understanding, elementary teachers by and large do not have the capacity to drive the integration of content across subjects, ultimately limiting their ability to teach math in applied and integrated ways.[83]

Even given these challenges, many organizations are currently working to build the confidence of teachers and school leaders around math, and to support elementary schools in becoming places where joyful math learning is happening. For an example, read the spotlight about the Early Math Collaborative at Erikson Institute in Chicago, found later in this section, a multidimensional national resource in early mathematics that empowers and supports teachers' access to better understanding of early math content and effective ways to teach it.

HOW YOU CAN TAKE ACTION

- **Teachers** can collaborate with STEM faculty, undergraduates, or graduate students to co-plan and then co-teach integrated lessons and units that use interdisciplinary tactics to build student interest in, understanding of, and love for math. This can also increase teacher content-knowledge and confidence, as well as respect for and interest in the teaching profession. For inspiration, see this out-of-school example run by the National Society of Black Engineers.

- **Curriculum developers** can develop resources that enable teachers to integrate their math instruction with other subjects and connect it to students' lives, helping students to experience the power and potential of math.

- **District leadership** can encourage school leaders and teachers to experiment with more innovative methods of gauging student learning. For inspiration, see the resources developed by a 100Kin10 Project Team that focused on performance-based assessments for middle school science and learn more about the work of the Assessment for Learning Project.

- **Teachers,** especially with encouragement from school leaders, can incorporate personalized instruction into their lessons to help students with diverse strengths and needs achieve strong math outcomes and become increasingly interested in the subject. Bank Street and EDC's Center for Children and Technology's Math for All program (featured in an earlier call-out) focuses on supporting teachers to build these skills.

ACTIONS I WILL TAKE...

FIRST STEPS TO GET THERE...

- [ ] ....
- [ ] ....
- [ ] ....

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ERIKSON INSTITUTE

For readers who may not be familiar with your organization and work, please provide a brief description of your organization.

The Early Math Collaborative at Erikson Institute in Chicago is a multidimensional national resource in early mathematics. We expand access to mathematics for young children by reaching childcare providers, early childhood teachers, and teacher educators through professional development (PD), research, publications, conference presentations, and a robust online presence at earlymath.erikson.edu. While many of our services are offered through contracts with centers, schools, or districts, we also provide opportunities for individual teachers at our Summer Institute series. Our website is loaded with videos of children solving mathematical problems and terrific early childhood teachers leading powerful math lessons. The content is all free, and while most of it is available to all comers, joining the Collaborative (no fee) provides access to additional resources. We publish a free bimonthly newsletter with articles and links to useful ideas on our own website and others, and have an online presence on Facebook and Twitter.

Our professional development has been shown to significantly increase children's learning by shifting teachers' attitudes, knowledge, and teaching practice related to mathematics. Our book, *Big Ideas of Early Mathematics*, is used in teacher preparation and continuing education settings across the nation and internationally. As a part of Erikson Institute, a graduate school in child development, the Collaborative provides master's-level internships and doctoral fellowships to help prepare scholars of early math teaching and learning who continue to propel the field forward.

How is your organization working to improve foundational math?

It is our conviction that the most important thing we can do to empower and support teachers is provide access to better understanding of early math content and effective ways to teach it. Early childhood and elementary teachers, through no fault of their own, are generally underprepared to teach mathematics. For years, teacher preparation programs have been short on thoughtful math content, and math education departments have underestimated the important and profound kinds of math learning that take place before third grade. Our book for teachers uses over 40 years of cognitive developmental research to help adults understand the highly abstract thinking that goes into number sense, the counting process, and other foundational math. There is a lot for teachers of young children to know about math and its teaching that goes beyond the layperson's knowledge of mathematics. Spelling that out for teachers in ways they can grasp shifts their ability to help children's math thinking develop.

Further, we address teacher attitude directly. Many early childhood and elementary teachers are truly the "walking wounded" when it comes to mathematics. They need to have their own new and positive experiences with mathematics, both so they will be open enough to learn more about it with us in our PD sessions and also so they can teach it to children with joy, confidence, and enthusiasm. Our first meetings with a new group of teachers always directly address the very common fear and uncertainty many of them feel about doing and teaching math. We begin each session with adult learning activities that are complex enough to be engaging for adults but that highlight some of the concepts and thinking that young children need. By emphasizing group work in a supportive cohort environment, modeling willingness to allow time for productive struggle among our students, and employing an approach to mistakes and misunderstandings that emphasizes them as opportunities to learn, we reeducate teachers around mathematics, giving them a new vision for what it can be like to learn and to teach it.

Finally, we make extensive efforts to connect the PD work we do to teaching practice. We do this through many different channels. During PD sessions, we watch and analyze a lot of video, both of children doing mathematics and of teachers working with children. We study transcripts of classroom interactions between teachers and children, applying rubrics and frameworks that help us identify key teaching strategies. We provide sample lessons for teachers to implement in their classrooms that emphasize the math concepts we have just been studying. When possible, we provide on-site coaching and utilize video to help teachers see and reflect on their own work. We have developed a formative assessment protocol for teachers to use when they have the opportunity to meet together at their school setting. Grade-level (or other) teacher groups use the protocol to select a task, anticipate student responses to the task, and organize a shared discussion of the results. By providing a structure teachers can use at their school, we embed a focus on the students and their math learning that pushes teachers to continue to think deeply about math content and to develop a shared understanding of what their students are learning.

What is core to your work? What are the one to three elements that are critical to its success?

Our work has two pillars: the Big Ideas and the Whole Teacher Approach. The Big Ideas (see our book referenced above) are a set of core concepts we have identified that are central to the mathematical thinking and development of young children. While they cannot be directly taught, they represent truths that preschoolers and grade-schoolers need opportunities to wrestle with and discover for themselves. For example, the idea that "quantity is an attribute of a set of objects" is key to a useful understanding of what a number is. Teachers who are aware that young children need time and opportunity to build this understanding are more likely to provide meaningful opportunities to associate number words and amounts together. Teachers who are guided by the Big Ideas in their math teaching are better prepared to seize opportunities for making important conceptual connections, as well as adapt curriculum to feature those ideas children are struggling with most.

The Whole Teacher Approach is a framework that guides our own work with teachers and administrators. It is based on the "whole child approach," which posits that early childhood and elementary educators cannot focus exclusively on the development of children's knowledge, but must also consider their physical and socioemotional development. In our work, we have adapted this idea to reflect our belief that the best way to help teachers learn and make positive changes in their teaching practice is to simultaneously address not only their knowledge for teaching, but also their attitudes and confidence related to teaching, and their teaching practice itself. This tripartite approach to our own work is reflected in each of the intervention components we utilize, including workshops, coaching, grade-level meetings, and instructional leader support. We believe this framework makes our PD substantially more effective than it would otherwise be.

How do you know this is working? What results have you seen?

We have demonstrated significant positive impacts on children's learning outcomes in three separate studies, most recently in our NSF-funded efficacy study of Collaborative Math, a PD program designed to create sustainable centers of excellence in early mathematics (p < .0001; g = .47). Additionally, we have seen that these shifts in child outcomes coincide with positive shifts in teachers' confidence in their math teaching, suggesting the importance of attitudinal and belief variables for good teaching (p <.001). Teachers and administrators alike have told us how powerful the program is for their own learning. Regarding their students, school and center staff report higher end-of-school-year scores on mandated assessment measures and a marked increase in the amount of math-related language children are using.

Looking to the future, where are you planning to improve or expand to make a bigger impact?

Currently we are developing a new online course, focused on math teaching for first to third grade and offered as part of a STEM-focused master's degree at Erikson Institute. Student teachers will study science, technology, and engineering — each in one course — and have two classes focused on math content and a capstone assignment that brings the topics together. We have already developed and delivered the first math class, which focuses on preschool and kindergarten mathematics, and are currently writing modules for the second course, designed to prepare student teachers to work with older children.

This online course will reflect our thinking about the centrality of Big Ideas and the usefulness of the Whole Teacher Approach as a framework for conceptualizing adult education efforts. The math content, however, will be quite different, particularly since between kindergarten and first grade, children begin to use math notation to keep track of and describe their thinking. This means teachers must support the development of that notation and also the many new ways of thinking about numbers that result. It is during these grades that children begin to be ready to talk about "three" as a concept unto itself, separate from three spoons or three trees, and when they do so, the possibilities for what we can do with mathematics expand dramatically. Place value, conventional subtraction and addition techniques, two- and three-digit numbers, grouping and unitizing strategies, 100s charts, early examples of multiplication and division, and eventually, fractions, are all part of the mix.

In order to address this content, we have extended our number core-related Big Ideas "upward." For example, our Big Ideas intended for grades 1, 2, and 3 include the concept that "a whole or unit can be divided into equal parts in many different ways." As with the Big Ideas we have developed for preschool and kindergarten, these are concepts that children need multiple opportunities to discover for themselves, learning through application how they help make math flexible and adaptable. Throughout the course, our emphasis will be on making "school math" more like "real mathematics;" that is, we will give our student teachers strategies and ideas for helping children experience productive struggle, describe and defend theories about how things work, see more than one way to solve a single problem, and generally experience mathematics as meaningful (and pleasant!). We will encourage our student teachers to make math class a place where there is a lot of discussion and debate, and children have multiple opportunities to learn with and from one another.

About Spotlights

This research identified several organizations and models currently working to better equip elementary teachers to enable authentic and joyful math learning for all students. While these spotlights are at different points in their development and implementation, we believe all are promising places for the field to learn from when considering how to make progress on foundational math proficiency. 100Kin10 compiled these spotlights by inviting organizations to share core elements of their foundational math work through an interview-style questionnaire.

06

PERCEPTIONS OF MATH

How might we engender widespread belief that math is an essential subject for all citizens, not just for a few?

EVEN IN 2019, more than two decades after Barbie stopped saying "Math is hard," the prevailing belief in our country is that one can still be successful in life even if one is "not a math person." Similarly, the idea that it's okay if one is "just not any good at math" is commonplace. We have all likely heard friends, colleagues, or family members, and possibly even our teachers, use these phrases, only to be met with nodding heads rather than negative reactions. We may have said them ourselves. Beliefs such as these are both pervasive and accepted in our society. And they translate too-clear expectations on the part of school leaders and teachers — and of families and students — about whether all students can enjoy and be successful at math, both in school and when applied more broadly to their lives.

WHAT CAUSES THIS PERSISTING ISSUE?

01 Beliefs about the importance of math skills and knowledge for all citizens influences the prioritization district and school leaders place on ensuring elementary teachers have the resources and support needed to be effective math teachers.

02 Many families and caregivers have similar beliefs about math, leading to even stronger messages for children and impacting their ability to support their children's math learning.

03 Low expectations about the extent to which students of color and girls can be successful at math are still far too prevalent and serve to perpetuate beliefs that math is not "for all."

04 Students of color and from low-income communities often lack access to high-quality STEM teaching, working to limit experiences that will prepare students for future jobs in STEM.

First, beliefs about the importance of math skills and knowledge for all citizens influences the relative prioritization district and school leaders place on ensuring elementary teachers have the resources and support needed to be effective math teachers. Ultimately, this can have a negative impact on whether all students have opportunities to be joyful math learners and learn foundational math in authentic ways. As shown earlier, district and school leaders have deprioritized math when allocating resources, such as for teacher professional development and coaching roles. Elementary schools, if they have access to a math specialist or coach, likely share that person with several other schools. As noted earlier, our Brain Trust and interviewees described the great emphasis in recent decades placed on literacy education throughout the PK–12 field and society more broadly, often to the detriment of math education. While the notion that all children should be readers by third grade is widely known both in and out of schools, there is not a similar ingrained expectation that all children can and should achieve an understanding of foundational math concepts in the elementary grades, even with research showing that early math skills are one of the best predictors of later success in both math and literacy.[84] Therefore, schools and districts have less impetus to apply needed resources to meeting this goal.

Second, these beliefs extend to many parents and other family members. When families espouse similar beliefs that math is not for everyone, this message becomes pervasive for children and even harder to counteract. As our Brain Trust members note, beliefs about math on the part of parents or other caregivers often stem from their own feelings of discomfort with math or negative experiences when they were students. Comfort (or a lack of it) with and knowledge of the subject matter children are learning also influences families' ability to successfully help their children learn, and those who feel anxious about subjects like math may avoid helping with that content or may pass that anxiety onto their children.[85] This is yet another example of the fractal concept emerging: In too many cases, those working in education and families reflect the wider societal devaluing of or discomfort with math, which influences students' experiences.

When parents lack confidence in math, or believe they or their children may simply not be "math people," they tend to stay disconnected from their children's math experiences. This is detrimental to their student's success, as research demonstrates the strong relationship between family involvement and student's academic learning, and in particular shows that family involvement has a significant positive impact on foundational math learning. Yet many parents believe that "teaching math is the school's job," whereas helping their children learn to read is something they are responsible for and should actively support.[86] In many cases, family disengagement leaves them unfamiliar with the strategies their children are encountering, which may be very different from the procedural math they encountered as students. This can create unease on the part of parents when faced with supporting their children's math education, and can sometimes create situations where students are taught math differently at home as compared to in school. It often leads to families pushing back against authentic (and to them, unfamiliar) styles of math instruction, further encouraging school leaders and teachers to stick to inauthentic and joyless methods of teaching.

Third, while our society's broad beliefs (or lack thereof) about math as an essential subject for all are extremely important, questions about equity for students of color and from low-income communities are also at the core of discussions about math for all. Historically, STEM has been perceived as a subject where white men prevail. Given the prevalence of these biases, we should not be surprised to find that even among teachers, we see lower expectations for what students of color and girls can achieve in these subjects. Studies show that students live up to what their teachers expect of them, demonstrating the harmful impact of these negative biases. As one economist studying education policy at American University said, "The high expectations actually motivate kids to do better. Black students are hurt by that lack of optimism that white kids get, and black kids with black teachers rise to meet their [higher] expectations."[87] Moreover, we see similar issues with girls; when reminded of their gender, their beliefs about what they can achieve in the realm of mathematics shifts negatively, demonstrating the strength of students' concept of their own abilities, which in turn is heavily driven by teachers.[88] (Referencing the previous section, it's important to recognize how a teacher's expectation *and* anxiety influence students' beliefs about their math abilities.) Training teachers to recognize and address their biases does make a difference, which is certainly an encouraging finding. But on its own, this strategy is insufficient.

Fourth, students of color and those from under-resourced communities often lack access to high-quality STEM teaching (and as previously noted, teachers are the greatest factor in a student's learning). This serves to perpetuate beliefs that math is not "for all" and limits access to the STEM learning across the PK–12 experience that will prepare them for future jobs in STEM. In many cases, high-poverty schools are those deemed "hard to staff," with a higher percentage of new teachers, sig-

HILLSBOROUGH COUNTY PUBLIC SCHOOLS

Hillsborough County Public Schools shares the story of how they developed Connecting Academics and Parents sessions to help their community understand the shifts they were seeing around math instruction.

With the implementation of the Common Core State Standards, and later with the Mathematics Florida Standards, math assessments looked different, homework shifted focus, and the anecdotal reports to parents from children on "What did you do in math class today?" changed for many students in Hillsborough County Public Schools. It was only natural that parents and community members began to have a lot more interest in what was happening in this "new" math class. Our phones in the elementary math department began to ring more than ever before.

Our team knew that we needed to help our community understand some of the shifts that were occurring, why they were important, and how these shifts would lead to a deeper understanding of mathematics for all of our students. And importantly, we needed to educate them on effective ways to support their children's learning. Using guidance from the 100Kin10 publication "Plagiarize This: A user-friendly guide to talking about college and career-ready standards with just about anyone," we developed a 90-minute parent/community presentation that our team implemented in the evenings at over 100 different elementary schools and community centers.

Through these presentations, we learned many things about our parent and community members' thoughts and questions about mathematics and mathematics instruction. Two main points, however, repeatedly found their way to the forefront of the feedback:

- Our parents and community members were hungry to learn more about the "different" instructional strategies that facilitated deeper student thinking.
- Listening to a "district-level math team member" was fine, but they really wanted to hear from a teacher at their child's school (and the word of that teacher tended to carry more weight than the "district-level math team member").

Taking this feedback into account, our math team set out to create easy-to-use tools that would support our teachers in providing additional opportunities for parent and community members to experience and learn more about the math and connected instructional strategies their students were being exposed to in the classroom. With support from a grant through the Carnegie Corporation of New York, our team developed six different parent/community member presentations for each grade level. We call them Connecting Academics and Parents, or CAP sessions. The CAP presentations covered the concepts and instructional strategies that teachers reported were most difficult to teach and/or parents were most unfamiliar with.

The idea behind the development of these presentations was to provide teachers with a "ready to use right out of the box" tool for connecting with their parents/community. Each session includes an engagement activity to put the adult participants in the role of a student learner, opportunities to explore actual tools their children use to make sense of the mathematics, and a follow-up game or task they can do at home to connect with their child and support their learning.

Work Environment Connection: When schools have a positive work environment, teachers thrive and continue to grow in their profession. As a result, their instruction improves and student learning soars. Read more about the importance of nurturing positive work environments for teachers in our "Teachers at Work" report.

nificantly more vacancies to fill due to higher attrition rates, and more difficulties hiring for those open positions. Moreover, schools that serve students of color and low-income students also have far fewer STEM course offerings than those that white, economically advantaged students attend. During the 2013–2014 school year, only one-third of high schools where black and Latinx students made up three-fourths or more of the student body offered calculus, and these schools were less likely than other schools to offer physics and chemistry courses.[89] All of this adversely affects students, whose learning outcomes suffer from not only an outsized percentage of new teachers, but also from high rates of staff turnover.[90] It is worth noting that low retention rates are strongly tied to poor work environments; nurturing schools to be places where teachers thrive has a direct impact on student learning, including foundational math learning, and especially for students typically not exposed to quality STEM learning.

All of this happens across the backdrop of a chorus of voices calling for more diverse contributions to the STEM workforce. Few disagree that increasing the perspectives around the proverbial STEM table is not only important for our progress in STEM fields but also an essential component to ensuring equity for all. However, this belief does not always trickle down. In other words, it can be easy to overlook how diversifying the STEM workforce does not begin with hiring practices or college admissions or even high school course requirements. Instead, it begins in elementary school, where teachers are building the foundations of lifelong opportunity.

Exciting work is happening to change these views in several communities. For example, Hillsborough County Public Schools has developed evening presentations for parents and community members to give these adults opportunities to experience and learn more about math and the instructional strategies students are exposed to in the classroom. Hillsborough also created CAP (Connecting Academics and Parent) sessions to support parents with concepts and instructional strategies they may be unfamiliar with. The East Bay STEM Network has worked on multiple fronts to increase awareness of the importance of foundational math through activities such as developing an action plan, presenting early math policy recommendations to the state legislature, and engaging business and university leaders to publicly voice their support of collaborative work to highlight foundational math.

HOW YOU CAN TAKE ACTION

- **District leadership** can organize community nights to give parents and families the opportunity to experience the math curriculum and understand how they can support their child's math learning at home. A great example of this is Hillsborough County Public's Schools Connecting Academics and Parents sessions.

- **Curriculum developers and STEM-rich institutions** can develop fun, low-cost, and experiment-based activities for families to do math together at home or in their communities. STEM-rich institutions can also build these activities into their existing exhibits, and other community-based organizations can build math activities into their events. For example, the Minnesota State Fair developed "Math On-A-Stick," where all visitors are invited to explore math in unexpected ways and in a casual, fun setting.

- **Researchers** can expand the knowledge base about how to best engage families in math learning. There remains a scarcity of studies about the impact of interventions specifically targeted to family involvement and foundational math learning. Carnegie Corporation of New York is leading efforts to deepen the research base, as well as to address other issues related to bridging the gap between home and school and meaningfully engaging families and communities in demanding a quality education system.

- **Children's book publishers** can incentivize publications that integrate math and literacy and make math learning easy for families. Bedtime Math is a great source of inspiration. Alongside this, distributors can work to get these publications featured in online or retail spaces so that families can easily find them.

- **Teachers** can actively identify and then counteract their own biases about who can and cannot excel in math, especially as they relate to students of color and girls.

EAST BAY STEM NETWORK

The Institute for STEM Education at CSUEB leads the East Bay STEM Network, which serves as a hub organization for systemic STEM education reform. The Network regularly convenes key stakeholders — including leaders from industry, local and state governments, educators PK–16, and non-profits, many of whom had not previously worked together — to forge a regional STEM education effort that U.S. Rep. Barbara Lee of California has lauded as one of the most effective in the nation.

The Network identified early math as a key priority in STEM education and has published two reports with this message. The Network then developed an action plan to increase awareness of foundational math in terms of overcoming significant achievement gaps, developing the STEM workforce, and educational success in general. The action plan includes the Early Math Policy Recommendations, which have been presented to the state legislature's Assembly Select Subcommittee on STEM Education and featured in the San Francisco Business Times. President Leroy Morishita of CSUEB, who co-chairs the STEM Network, has authored op-ed pieces about why a college president cares so deeply about the math skills of three-year olds. The Network has launched pilot projects to generate family engagement and confidence in early math education and published a colorful "math games" booklet for families, which is receiving wide local distribution. The Network plans to continue this campaign.

Three principles core to the Network's efforts from the Institute for STEM Education:

"

01 **Advocacy and understanding from multiple stakeholders.** These issues are structural, and too complex, to be addressed by the education community alone. We could not advance public awareness, change prospective teachers' attitudes toward math, and engage low-income families without significant perspectives and assistance from the different people we bring together with a collective focus, with collective expectations that we can and must make a difference.

02 **The standing to work within the systems where we CAN make a difference.** As a CSU campus, we have strong relationships with county Offices of Education, K–12 administrators, legislators and other policy makers, and faculty on our own campus committed to STEM education. Our other partners have similarly relevant connections in the worlds of business and education. This is important to our ability to be heard, and to gain trust in the face of these large structural challenges.

03 **The sustainability of our organization.** The Institute and the East Bay STEM Network have been able to develop a stable base of funding, due in large part to the fact that CSUEB began devoting funding to support the Institute as the original grants began to expire, and also to the fact that we have attracted STEM education research grants and private philanthropy. This frees us to think in long-range terms, and to be guided by the leadership of the campus so that we can engage credibly with other leaders to make change happen."

Thinking about the future of its work, the Network relies on its "Roadmap to STEM Success," one of several founding documents developed to guide its long-term work. There are many identified challenges to STEM success for a diverse community, and the Network seeks to address them as opportunities present themselves, and with the understanding that this is long-term, multifaceted work. Looking to the future, they seek to increase public awareness and urgency about foundational math, expand family engagement in math education, and continue work to properly prepare educators of children from birth to age 8.

ACTIONS I WILL TAKE...

FIRST STEPS TO GET THERE...

- [ ] ....
- [ ] ....
- [ ] ....

SOURCES

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CONCLUSION

PLANES OFTEN CRASH FOR MULTIPLE REASONS.

> “THERE’S NOT ANY ONE SINGLE FACTOR THAT CAN BE POINTED OUT AND CHANGED; INSTEAD, IT IS A SERIES OF SMALL MISTAKES, MISSED OPPORTUNITIES, FAILED COMMUNICATIONS.”[91]

In response to this terribly simple and yet extremely profound truth, the National Transportation Safety Board has committed to a deliberate approach that examines each factor of a plane crash. After each crash, they create a chronological map of every detail, including the action (or lack of action) of every single player, noticing any small missteps or out-of-sync activities. They also work in teams, not as individuals, and disregard segregating characteristics such as title and rank that often reduce or minimize perspectives. This has resulted in giant leaps toward reducing crashes. The cost of weak foundational math to our society and to millions of young children and their communities is no less dire (if less dramatic) than plane crashes, and deserves the same coordinated attention. Let’s consider our ecosystem with a similar approach.

Assuming this mindset, each student who makes it through elementary school without a foundational set of math abilities suffers from a series of missteps and mistakes, some that touched him or her directly and others that seem far removed. No matter how near or far they appear to be, each and every player in the foundational math system holds a piece of the puzzle and is responsible for contributing their part to the whole. To dramatically reduce the number of children suffering from a combination of compounding errors — especially because it’s children of color or from low-income families who experience more of these mistakes than others — we must work together as teams, connect our systems and make them more efficient, and recognize that both success and failure require a combination of factors, interventions, and solutions.

We created this report to enable diverse players to contribute and coordinate their actions to improve foundational math proficiency for young learners, especially girls, students of color, and students from under-resourced communities who most often miss out on strong math learning in grade school. The spotlighted models and immediate actions offer clear strategies for how to avoid some of the mistakes or small missteps. But enacted on their own, any one of these solutions won’t lead to the type of change that can be experienced by children, families, or communities.

Let’s take a step up and out of the details. Looking across the six big issues that influence foundational math proficiency, three crosscutting areas and corresponding actions can enable authentic and joyful math learning for all students.

Build vision and coherence around foundational math learning. Teaching is a practice-based profession, and candidates need rich opportunities to practice what they’ve learned in environments that support and extend their coursework in order for those learnings to take hold and be mastered. Yet elementary teachers’ professional experience is too often disjointed. There is little coordination among those responsible for the different elements of their preparation, and as a result, teacher candidates often experience their courses and field-based training as one-offs, rather than as pieces of a whole. This problem only worsens when they join a school team that may or may not share beliefs about how foundational math should be taught. With the focus so often on either literacy or test scores, there is rarely a shared school-wide approach to math.

Developing a shared understanding of what math learning should look like and accomplish among all the players in the ecosystem — including preparation programs, school communities, policy makers, and professional development providers — has the power to dramatically shift how teachers and students experience math in elementary schools. In short, all of those responsible for foundational math learning need to rally around a vision of what excellent math learning in elementary school looks like and achieves, and build coherence across their various roles and responsibilities accordingly.

Explicit and extensive collaboration between teacher education programs and school districts yields increased coherence, in particular among players operating in a shared geography or with a common group of teachers. This can start with higher education institutions and school districts coming together to set a common vision for what is expected of teachers at each stage of their career, followed by intentional partnerships and ongoing communication and coordination around everything from overarching philosophy, pedagogy, and curriculum to field-placement expectations and supervision. Similarly, teacher preparation programs can help support alignment with districts and school management organizations by introducing high-quality instructional materials to teachers within the preparation programs. Fortunately, there are some promising examples we can learn from, such as Relay Graduate School of Education, High Tech High (see prior call-out box), Rider University (see prior spotlight), and several teacher residencies, especially those that partner with the National Center for Teacher Residencies.

Foster a more connected system across the elementary STEM teaching profession by setting a foundational math vision and building the connections to achieve it, both within the preparation and in-service spaces and between them, especially inside of focused regions. Doing so will enable foundational math advocates to...

Revise expectations of elementary teachers' responsibilities. Putting aside the many noninstructional roles they play (trusted confidant, recess monitor, cheerleader, emotional referee, etc.), elementary teachers are responsible for a vast amount of instruction. They teach students to read and write and build a foundation in number sense, alongside instilling a basic appreciation for social studies and human history and sparking an interest in science and computational thinking. As a result of this range of responsibilities, it is nearly impossible for one single person to be expert enough across all of these areas; moreover, it makes preparing and supporting teachers across all of these areas equally difficult. As one researcher aptly put it, "The fact that many elementary teachers lack the knowledge to teach mathematics with coherence, precision, and reasoning is a systemic problem with grave consequences. Let us note that this is not the fault of our elementary teachers. Indeed, it is altogether unrealistic to expect our generalist elementary teachers to possess this kind of mathematical knowledge."[92]

It's time to acknowledge that the common approach to each elementary teacher delivering all content negatively impacts many elements that lead to authentic and joyful math learning (no doubt among other areas equally impacted). Doing so will require reworking staffing models, revising preparation pathways, and changing the general perceptions many of us have about what elementary school is.

Revamp the job description of elementary school teachers, reducing the scope to what is reasonable, and then prepare and support teachers accordingly. Doing so will support foundational math advocates to...

Bring foundational math into the 21st century. Foundational math exists in a sort of Back to the Future situation, wearing Western frontier clothes or neon '80s garb in the middle of a country running on technology unimaginable just 10 years ago. At nearly every point in the ecosystem, we see how different players are failing to catch up to what our students need out of their foundational math learning in 2020 to be prepared for a life of opportunity and choices. Most teacher preparation faculty have little idea of what the best teachers are doing in classrooms today; many school leaders and teachers are too stifled by the constraints of the system or their own anxieties to try a new kind of instruction; and many families expect that their student's homework should look just as theirs did 30 years prior. Even with nearly society-wide recognition that technology and innovation drive our collective future, too many fail to connect the dots and recognize how foundational math instruction must change to prepare students for this new reality.

An antiquated view of math is not the only challenge we face in transforming how the subject is taught in elementary school. We also must face the reality that many STEM enthusiasts begrudge math and the relative attention it has received over other STEM subjects due to the focus on testing. All the while, others cannot accept that foundational math is just as important as literacy. That said, these specific viewpoints can also be addressed by bringing foundational math learning into the 21st century and demonstrating that innovative math instruction allows for more holistic and interdisciplinary learning and greater opportunities for our youngest students. The time is ripe to shift these experiences and beliefs, whether among faculty, teachers, families, school leaders, or policy makers, and recognize math as a core element that is strengthened by and in turn strengthens a child's whole education, including reading and STEM more broadly, and prepares her to be a contributor to our future economy, democracy, and society.

Revolutionize foundational math by educating stakeholders across the ecosystem about what authentic, joyful, and effective math looks like in 21st-century elementary schools. Doing so will lead to...

Authentic, joyful, and effective math learning for all students.

But where to begin on such big charges? The highest-leverage catalysts – the elementary STEM (and specifically math) expertise of faculty and their modeling of instructional practice – offer clear strategies for focusing and are the most direct path to making these changes. As a reminder, the catalysts are the greatest leverage points for change across the Grand Challenges. They reflect the synthesis of tens of thousands of data points on which issues, if improved, would generate a domino effect and the most improvement across the system.

Remember Maria? Now imagine that while Maria is in her third year of teaching, her local university recognizes that too many of their math-content faculty have not set foot in an elementary classroom since they were students and have little idea of what effective teaching looks like. The university reaches out to the local school system to see if their professors can come and observe a bit of foundational math in action. Maria, as an alum, is chosen to participate. The teachers and faculty alike rave about this early collaboration, citing learning and inspiration for all. As a result, the faculty start talking more across traditional siloes back at the university, but also to teachers and district leadership about what is expected of elementary teachers when it comes to math and how preparation should be shifted to meet that. They realize that what teachers need from their pre-service experience cannot be adequately met, because they need to know too many things.

A diverse committee comes together to see how preparation, policy, staffing structures, and school design can change to enable a more realistic and effective elementary teacher role. Members include representatives from the university leadership and faculty, the school district, the PTA, the local museum, and several local schools. Together they develop a shared vision for elementary math learning and map out how each of them contributes to achieving it. As this work happens, math faculty also begin to integrate what they are learning about effective instruction into their classes with other student populations, and to share some of these ideas with colleagues at department meetings. Over time, more and more students are graduating from the university with more positive feelings about math. Simultaneously, the diverse committee is making inroads, and early results include Maria and some of her colleagues using more authentic math instruction in their classrooms. Parents are noticing that their kids come home excited to show what math they learned that day, and they reach out to Maria and the other teachers to learn what's new.

Fast-forward another few years. Maria, who wasn't sure she'd make it past year three of teaching, is thriving. Her earnings allow her to maintain a comfortable lifestyle with several small luxuries. Her love of her job is so clear to her students that there are many pieces that begin with "I want to be a teacher..." on the "What I want to be when I grow up" display wall in the school cafeteria. She also continues to mentor prospective teachers, and is currently assigned to work with Nico. Maria shares the new strategies with him. Nico is encouraged because these are just the strategies he and his classmates learned about from their faculty. Nico joins Maria's school as a full-time teacher the following year, and his role is focused. He is teaching second-grade STEM, while Maria is focusing on literacy and social studies. They are both supported by specialized coaches in the various subjects they cover. Parents have insisted on expanding the science fair to the STEM fair. What's really exciting for Nico and Maria is that their principal is specifically decreasing the focus on this year's assessment scores, pointing to the many other accomplishments the school is making, and encouraging new ways of gauging student learning.

At the same time, the work of the committee is paying off. More kids across Maria and Nico's town are experiencing authentic and joyful foundational math in school, and as a result more students — specifically girls, students of color, and students from low-income neighborhoods — will enter local middle and high schools with the confidence and skills they need to flourish in higher-level STEM courses. The colleges and universities in their state will see an influx of students ready for and interested in STEM majors, leading to a larger and more diverse STEM workforce. Thanks in large part to this growth of STEM talent, Maria and Nico's community is having a resurgence several years later, with more local businesses, cultural institutions, and community groups emerging. It's even recently made the list of the top 10 trending cities.

Maria and Nico… they are only fictional. But imagine if their experience became the norm, zooming out to see it across the country. All together, this translates into more people representing a greater range of perspectives and experiences contributing to society and to solving the most pressing domestic and global challenges we are facing in the 21st century. Returning to our overarching realization about how essential it is that teachers experience the kind of instruction they themselves will need to use, we see here how a teacher's impact can ripple: starting small with joyful and authentic student learning in their classroom and growing ever bigger to impact the learning in their local university, and then the industry and innovation in their city, and finally reaching national scales.

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CONSIDER THE CATALYSTS IN PARTICULAR!

HOW CAN YOU CONTRIBUTE TO IMPROVING FOUNDATIONAL MATH PROFICIENCY?

WHAT ARE THREE IMMEDIATE ACTIONS YOU'LL TAKE AFTER READING THIS REPORT?

- [ ]
- [ ]
- [ ]

RESEARCH SOURCES

FOUNDATIONAL MATH BRAIN TRUST MEMBERS

A Brain Trust of 100Kin10 partners and Teacher Forum members acted as advisors and thought-partners throughout the writing of this report. Members of the Brain Trust guided the research and analysis, contributed firsthand experience in and knowledge of the issue, and helped shape findings, including providing feedback on research findings to ensure accuracy and relevance.

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EXPERT INTERVIEWEES

Over the course of this research, interviews were conducted with the following sources:

- Rachael Aming-Attai, University of Indianapolis
- Jo Boaler, youcubed at Stanford University
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- Megan Franke, University of California, Los Angeles
- Bruce Simon, Institute for STEM Education at California State University East Bay
- Babette Moeller, EDC's Center for Children and Technology
- Jim Short, Carnegie Corporation of New York
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100Kin10 unites the nation's top academic institutions, nonprofits, foundations, companies, and government agencies to address the nation's STEM teacher shortage. Together we are tackling systemic challenges and getting 100,000 excellent STEM teachers into classrooms nationwide.

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