EF+Math Program

aerdf

Strengthening Executive Function Skills to Improve Mathematics Learning

Evidence of Promise from EF+Math's Inclusive R&D Approach

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Acknowledgments

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About the Advanced Education Research and Development Fund (AERDF)

AERDF is a national nonprofit R&D organization launched in 2021 that builds ambitious, inclusive three-to-five-year programs with education practitioners, aimed at tackling persistent teaching and learning challenges that disproportionately affect Black and Latino students and students of all races experiencing poverty in grades Pre-K–12. Each program builds on existing community-driven evidence and expertise as well as learning science to translate fundamental insights into usable knowledge, useful practices, equitable approaches and transformative tools for education practitioners as well as students. EF+Math was launched by Melina Uncapher in 2019 and served as a demonstration program that tested the core theory of action that helped launch AERDF, which has since produced two additional programs in 2021: Assessment for Good and Reading Reimagined.

Contents

Executive *Summary*

Students, teachers, and schools are in urgent need of bold, rigorous mathematics learning approaches that are developed and tested in real classrooms—and are proven to get results. Education experiences that are equity centered, based on learning science, and co-designed by educators, researchers, and developers have the promise of dramatically improving mathematics outcomes for Black and Latinx students and students of all races experiencing poverty.

At EF+Math, we are working to understand the promise of mathematics learning approaches, co-designed with students and teachers, that combine executive function (EF) skills, conceptual understanding and multi-step problem solving, and equity. EF+Math has early evidence that shows the positive impact of this unique approach.

The EF+Math insights report shares promising preliminary findings from EF+Math's portfolio of ten teams, each made up of students, educators, researchers, and developers who collaborate through a unique Inclusive Research and Development (R&D) approach.

Our Inclusive R&D model places an intentional focus on equity throughout the R&D process and centers educators and students as crucial partners from the start, working alongside researchers and developers throughout cycles of design and research. These teams are in the third year of a five year R&D cycle to design, build, pilot, and evaluate mathematics learning approaches and new research tools. This report shares insights from what teams have learned so far.

Our Insights

After many iterations of R&D in co-leadership with educators and students, EF+Math project teams have developed novel mathematics learning approaches and begun testing their scientific hypotheses about the relationship between EF and mathematics through pilot studies in classrooms across the country. Below are insights from the work as a whole portfolio based on teams' early results.

- EF+Math approaches show promise for improving student learning.
- When educators and students are involved at every stage of the R&D process, learning approaches are more relevant to the classroom.
- Student mathematics learning outcomes are improved when executive function skills are strengthened alongside positive student beliefs.
- Effectively building students' executive function skills during mathematics learning requires new instructional strategies, tools, and assessments.
- New student-centered tools and assessments emerge when diverse teams focus on designing for equity.
- Centering equity from the beginning leads to mindset shifts and a culture of equity and inclusion throughout the process.

Call to Action

Early results show the potential of EF skills as a lever for improving mathematics learning, while simultaneously uncovering new information about the relationships between mathematics learning and EF skills; additionally, we are generating promising new assessment tools and learning approaches that not only benefit students now, but can also inform evidence-based design of future curriculum, learning technologies, and teaching strategies.

The impact of EF+Math's work is already expanding beyond our community, shifting influential individuals' and organizations' behaviors and actions to be more asset-based and equity-centered. EF+Math's intentional emphasis on equitable processes and equity-centered and engaged people is creating a ripple effect that is transformative.

As we continue in this process, we issue a call to action. **We invite additional partners to become part of this growing movement**, including new educator partners to join us and actively participate in the continued improvement and evaluation of these promising mathematics learning approaches. We see the promise for students with the adoption of Inclusive R&D practices and look forward to engaging with the broader community of educators, researchers, and developers to collectively advance the field towards Inclusive R&D practices.

With efforts from all of us across multiple sectors and with different areas of expertise, we can collectively transform mathematics education for our students and dramatically improve their mathematics learning outcomes.

Our Vision *& Approach*

Every student is a powerful learner capable of succeeding in mathematics.

At EF+Math, we want every student to know their innate abilities, know how to use them to take control of their own learning, and be given every opportunity to learn rigorous mathematics. To this end, we engage and support teams developing research-informed mathematics learning approaches for grades 3–8 that draw from the expertise of education practitioners and center Black and Latinx students and students of all races experiencing poverty. We seek to dramatically improve student academic outcomes in mathematics by strengthening the core assets every student has: executive function (EF) skills. Executive function skills are the core capacities that allow us to manage our attention, thoughts, emotions, and behavior. Every student has EF skills, and, like muscles, they develop more with practice.

Our teams of education practitioners, students, researchers, and developers co-design, implement, and evaluate a portfolio of innovative learning approaches. We bring these teams together through our Inclusive Research and Development (R&D) model, which places an intentional focus on equity throughout the R&D process and, from the start, centers educators and students as crucial partners working alongside researchers and developers throughout cycles of design and research. The teams are creating a portfolio of learning approaches and research methods that combine high quality and equitable math learning experiences with EF skill-building opportunities.

Executive function skills are the core capacities that allow us to manage our attention, thoughts, emotions, and behavior. EF skills include three separate and interacting processes:

+ **Cognitive Flexibility** refers to shifting one's attention between multiple tasks or perspectives.
+ **Working Memory** involves holding and working with information in one's mind.
+ **Inhibitory Control** means the ability to focus on the information that is important and ignore distractions (Miyake et al., 2000).

Now in our third year of a five-year R&D cycle, we see evidence of promise in our unique approach. Our teams' attention to equity and to educator voice in every stage of the R&D process is producing mathematics learning approaches that are aligned with classroom practice. Preliminary data from small-scale studies suggest many of our approaches are improving mathematics learning, and simultaneously we are increasing our knowledge of the relationship between mathematics learning and EF skills.

In the research conducted across our portfolio, students are advancing their multi-step problem-solving skills, building their identities as mathematical thinkers, monitoring their EF skills in real time—and more. This report shares early insights to date. School systems across the country are seeking evidence- and equity-driven pathways to support all students in reaching their full potential. These insights provide concrete examples of how we can create more equitable mathematics learning experiences for students by bringing together cross-sector expertise using equity-centered and inclusive R&D processes.

We hope these insights inspire you in your own work and that you'll consider joining us as partners in our next phase of work or as part of a larger community shifting to Inclusive R&D processes.

Equity in education is a condition in which uneven outcomes by group identity no longer exist. It is achieved when high quality learning opportunities are constructed for and with individuals who have been historically marginalized by centering their identities, values, and cultural wealth, while interrogating the roles of power, privilege, and sociopolitical forces that influence our current educational paradigm.

Our commitment to equity is described in the following principles:

+ Assuming and affirming the mathematical brilliance of Black and Latinx students and students of all races experiencing poverty.
+ Elevating students', educators', families', and communities' inherent strengths and voices, including knowledge, skills, beliefs, values, perspectives, and cultural background.
+ Striving for racial equity, while acknowledging the intersections of class, gender expression, sexual orientation, ethnicity, religion, nationality, language, and ability.
+ Staying sociopolitically engaged and responsive to the challenges of systemic racism due to systems and structures that perpetuate inequities.

Our *Work*

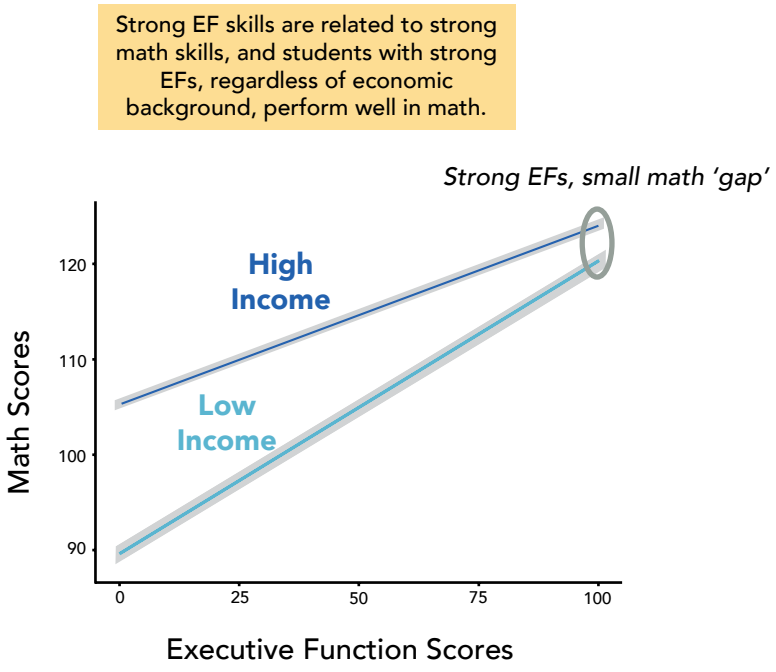
While students from any background are equally capable of success in mathematics, not every student has equal opportunities to succeed. Students who have historically and systematically been excluded from these opportunities—including Black and Latinx students and students of all races experiencing poverty—deserve access to the best resources and support to help them reach their full potential.

Our work is to research and develop mathematics learning approaches for these students that address three intersecting tenets: EF skills, conceptual understanding and multi-step problem solving, and equity. While many existing mathematics programs and tools use some of these principles, we are unique in creating learning approaches and research methods that combine all three. And our inclusive R&D process results in approaches that align with classroom practice, which drives more equitable, efficient, and effective outcomes.

All students have EF skills, assets students develop and use throughout their lives, in both school and non-school environments. Teachers have known for years that thinking flexibly to solve problems, filtering information to attend to critical details, and keeping operations and rules in mind are essential to mathematics learning. All of these abilities rely on EF skills. Strong EF skills can support students' actions to achieve their goals, including within mathematics learning. Research suggests that we can strengthen EF skills through contextualized development opportunities (Clements et al., 2016; Diamond & Ling, 2019; Strobach & Karbach, 2016). As we build on this research, we want to emphasize the importance of taking an asset-based approach to EF skills—in both awareness building and in skill building—so that EF skills can be leveraged to support students' agency.

EF skills are associated with mathematics learning outcomes. Prior research shows that not only can strong EF skills support increased mathematics learning, but strong mathematical understanding can also support the increased development of EF skills (Bull & Lee, 2014; Merkley et al., 2018; Miller-Cotto & Byrnes, 2020). **Figure 1** suggests that building EF skills may improve mathematics learning opportunities for all students. It also shows that for students with high EF skills, there is a smaller gap in mathematics scores between students from low-income and high-income households (U.S. Department of Education, 2019). This signals an opportunity for research to explore the potential impact of strengthening EF skills on improving mathematics learning outcomes for all students facing systemic oppression, including those who are Black and Latinx, as well as students of all races experiencing poverty. While educators who specialize in supporting students with learning differences often utilize strategies to help those students improve their EF skills, there is an under-tapped opportunity to bring explicit EF development into mathematics education for the benefit of all students.

Figure 1: Building EF skills may improve mathematics scores



Conceptual understanding is knowledge of relationships between mathematical ideas. It involves the ability to represent mathematics in multiple ways and to move across these representations depending on the needs of a particular context (National Research Council, 2001).

Multi-step problem solving is a process involving students' ability to formulate, represent, and solve complex tasks. Multi-step problem solving is often developed through tasks that are open-ended in design and offer multiple pathways to solutions. It often requires flexibility of reasoning and strategy to achieve the intended outcome.

The substantial evidence demonstrating the association between EF skills and math learning outcomes, along with prior research showing EF skills should be strengthened in the contexts within which they are intended to be used (Clements et al., 2016; Diamond & Ling, 2019; Strobach & Karbach, 2016) informs our core hypothesis: directly integrating EF strengthening opportunities within mathematics learning approaches will dramatically improve student outcomes in mathematics.

The two additional research-informed tenets of our approach are (1) creating math learning approaches that help students develop deep conceptual understanding and multi-step problem-solving skills and (2) intentionally designing for equity.

Conceptual understanding and multi-step problem solving skills are essential for students' mathematics learning (National Council of Teachers of Mathematics, 2014). Yet studies show that Black and Latinx students and students of all races experiencing poverty are less likely to have educational opportunities that foster conceptual understanding and problem-solving in mathematics (e.g. Berry, 2008).

EF+Math approaches embed EF learning opportunities within rigorous mathematics curricula that simultaneously support students' development of conceptual understanding and problem-solving skills.

Further, EF+Math projects are intentionally designed for equity. Studies suggest that instructional practices that give every student a chance to participate in mathematical discussions, foster their sense of belonging in mathematics classrooms, and develop their identity as mathematics learners may particularly benefit Black and Latinx students and students of all races experiencing poverty (e.g. Aguirre, Mayfield-Ingram, & Martin, 2013). EF+Math mathematics learning approaches build upon the work of scholars who center Black and Latinx students and students of all races experiencing poverty to drive instructional approaches which attend to culture, power, and privilege (e.g. Gutiérrez et al., 2018; Martin, 2012; Martin et al., 2010). The asset-based approach to EFs, which is a commitment within the EF+Math community, posits that developing and supporting EFs can lead to increased student empowerment and agency in learning.

It is through our Inclusive R&D model that we co-create math learning approaches that integrate these three intersecting tenets: EF skills, conceptual understanding and multi-step problem solving, and equity. Our Inclusive R&D model centers educators and students as crucial partners from the start, working alongside researchers and developers throughout cycles of design and research. As shown in **Figure 2**, Inclusive R&D is an interdisciplinary process that draws from rigorous learning science, practical educational expertise, and the ability to build education products, tools, and approaches. This model, which has been heavily influenced by Digital Promise's Inclusive Innovation model (Angevine et al., 2019), elevates equity, with individuals and teams committed to practices of interrogating bias and disrupting systemic oppression.

EF+Math intentionally structures and supports team dynamics and partner interactions to deconstruct hierarchies of power that arise implicitly throughout traditional R&D processes. Educators and students are involved in design, decision making, application, and research. EF+Math is building strong, diverse teams and actively supporting them in developing new educational approaches that prioritize equity and lead to improved learning outcomes for all students, with promising results within five years.

In researching and developing math learning approaches at the intersection of executive function skills, conceptual understanding and multi-step problem solving, and equity, we already see that the outcomes are greater than the sum of their parts. The power of the work ripples out across our community of over 250 members: students are deeply engaged with our pilot materials, teachers are feeling hope in the midst of national educational challenges, researchers are implementing new equity-centered, collaborative study design approaches that will outlive their tenure, and product development companies are transforming their methods—and we're only in our third year of a five-year R&D cycle.

Our work ahead is to continue with evaluation and ongoing iterative design and development of promising math learning approaches. This work is in pursuit of our goal of significantly increased numbers of Black and Latinx students and students of all races experiencing poverty in grades 3–8 who are proficient or advanced in mathematics skills.

Inclusive means both an equity-first approach as well as a community-based approach where the participation of educators, students, families, and community members is critical.

Figure 2: EF+Math Inclusive Research and Development Model

Researchers, developers, educators & students working together at all stages of design, development, research & evaluation with a focus on equity

Our *Portfolio*

EF+Math project teams are composed of education practitioners, students, researchers, and developers who bring their own unique perspectives and experiences together to co-design, develop, and research mathematics learning approaches. The portfolio also includes projects developing new tools to monitor and test the efficacy of new approaches and advance our knowledge of the relationship between EF skills and mathematical learning in real time.

All projects in the portfolio take different approaches to addressing the three intersecting tenets of EF skills, conceptual understanding and multi-step problem solving, and equity using an Inclusive R&D process. The portfolio of teams and approaches is intentionally designed to increase impact. The "power of the portfolio"—the benefits gained from this design—can be seen both in the way all teams contribute to the set of knowledge about EF, math, and equity, and in the development of collaborations across teams.

Combining the lessons learned from each of these teams testing their work in different classrooms and contexts across the country, we have created a learning community that will continue to advance math outcomes for students. By simultaneously testing learning approaches that improve math outcomes and conducting research that advances our understanding of the relationship between math and EF skills, we see both immediate impact for students and generation of new research findings that can help create more equitable, efficient, and effective math learning approaches for all students.

Collaborations across the portfolio demonstrate the power of simultaneous, collaborative, and iterative learning approaches and assessment development. The EF+Math Program and portfolio of project teams were originally designed and selected with these collaborations in mind.

Our Project Teams

CUETHINK EF+

A web-based learning system for facilitating collaborative mathematical discourse and problem solving with embedded executive function scaffolds to create safe spaces for historically marginalized students to express their ideas and share their thinking and reasoning. CueThinkEF+ is for students in grades 6-8.

Principal Investigator:
Sheela Sethuraman

Lead Organization:
CueThink

Enlearn: Elevating Math Knowledge, EF Skills, and Metacognition, and Making These Insights Actionable

Development of embedded, real-time measures of executive function skills in math based on digital student interactions and teacher observations. Insights from these measures will provide actionable, equitable insights to teachers in real time.

Principal Investigators:
Zoran Popovic & Yun-En Liu

Lead Organization:
Enlearn

fraction ball

A series of movement-based games that make meaningful connections between math learning in the classroom and the schoolyard and provide a playful context for students to engage in embodied rational number learning while strengthening executive function skills. Fraction Ball is for students in grades 3-8.

Principal Investigator:
Andres Bustamante

Lead Organization:
UC Irvine

MAT+EF: Developing a Low-Cost Mobile App to Reveal Excellence in EFs and Math Learning

Development of a set of reliable and equitable tools to visualize math skills and underlying executive function skills and dynamics in those functions using mobile app technology. Draws from successes in personalized medicine, applied for the first time in education.

Principal Investigators:
Susanne Jaeggi & Dennis Barbour

Lead Organization:
UC Irvine & Washington University in St. Louis

MathicSTEAM

An innovative three-layer instructional approach that uses interactive graphic novels, individual game-based learning, collaborative learning experiences that facilitate team work and academic discourse, and opportunities to engage in problem-based learning activities that link to math in the real world. MathicSTEAM is for students in grades 4 & 5.

Principal Investigators:
Twana Young & Martin Buschkuehl

Lead Organization:
MIND Research Institute

Mathematical Thinkers Like Me

An online collaborative problem-solving and storytelling program that supports students in developing their identities and strengths as mathematical thinkers with strong executive function skills. Mathematical Thinkers Like Me is for students in grades 6-8.

Principal Investigator:
Stephen Weimar

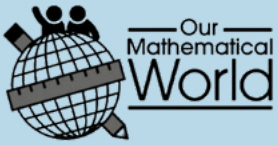
Lead Organization:
21st Century Partnership for STEM Education

Pennesota: Scalable, Multi-Dimensional Measures of Learner Strategies During Math Learning

Development of measures to reveal moment-by-moment learner strategies.

Principal Investigator:
Ryan Baker

Lead Organization:
University of Pennsylvania



A program that includes a sequential set of activities designed to center students as strong math problem solvers who use appropriate EF skills to guide their process. Our Mathematical World is for students in grades 3-5.

Principal Investigators:
Caroline Hornburg & David Purpura

Lead Organization:
Purdue University

Prather: Accurate, Precise, Equitable and Useful Models of the State of the Learner

Creation of a computational model that aims to understand an individual learner's behavior on math tasks while accounting for that learner's (1) internal cognitive and perceptual processes, (2) socio-emotional skills and current state, and (3) environmental context.

Principal Investigator:
Richard Prather

Lead Organization:
University of Maryland, College Park

SPARKmath
by Saga Education

A comprehensive set of supports for the math classroom that attend to cultural relevance, math identity and belonging, executive functioning skills, mathematization of concepts that students find relevant, the realities of classrooms and current practice, and classroom social norms. Spark Math is for students in grade 6.

Principal Investigators:
Brent Milne & Krista Marks

Lead Organization:
Saga Education

Our School Districts

Alum Rock Union School District, San Jose, CA

The Alum Rock Union School District in San Jose is nestled in the foothills of the Santa Clara Valley in the San Francisco Bay Area and is a family-oriented community committed to its children and schools. Alum Rock serves approximately 8,600 students in grades TK-8.

Attleboro Public Schools, Attleboro, MA

Attleboro Public Schools aims to be the center of a community united around education, where all stakeholders value and participate in our collective success. Located in Massachusetts, Attleboro is a suburb of Providence, RI, and serves about 6,000 students.

Cajon Valley Union School District, El Cajon, CA

Cajon Valley Union School District focuses on the positivity of each student's unique strengths, interests, and values. Serving over 60 square miles of San Diego's East County, Cajon Valley Union School District has approximately 16,000 students.

Hillside Public Schools, Hillside, NJ

The mission of the Hillside Public Schools is to provide all students the knowledge and skills needed to be successful, engaged citizens; citizens that contribute to the vitality of an ever-changing world through rigorous academic, culturally responsive, instructional student support programs. Hillside Public Schools serves about 3,000 students in northern New Jersey, just outside of Newark.

Middletown City Schools, Middletown, OH

Middletown City School District rallies around #MiddieRising, where they rise and unite, with education that inspires, unites, and transforms. The school district is located in Middletown, a small city in southwestern Ohio. The district serves about 6,200 students.

Newark Public Schools, Newark, NJ

Newark Public Schools is a large metropolitan school district serving more than 42,000 students in northern New Jersey, with a mission to deliver an academically rigorous and culturally responsive instructional program that prepares every student for success and builds knowledge, strengthens character, cultivates ingenuity, and fosters leadership.

Santa Ana Unified School District, Santa Ana, CA

The Santa Ana Unified School District is the second largest school district in Orange County serving approximately 45,000 children of Santa Ana and surrounding areas. The district is committed to providing each of its students with a high-quality education, rigorous and advanced programs, and a nurturing, safe environment with state-of-the-art facilities, 21st century learning and technology, and a direct pathway to college upon graduation.

Vista Unified School District, Vista, CA

Vista Unified School District works toward a vision where every student graduates from Vista Unified as a resilient, agile learner and creative problem solver who navigates the world with confidence and kindness and eagerly embraces local and global challenges. Vista Unified is a suburban school district serving approximately 25,000 students in Southern California.

Additional district partners include:

- A small rural district in the South that serves approximately 1,000 students
- A district in a mid-sized city in the South that serves about 5,000 students.
- A district in a large suburb of a Western city that serves approximately 9,000 students

Our *Insights*

Now in year three of five, we have preliminary findings that show the strong potential of our approach.

After many iterations of R&D in co-leadership with teachers and students, our project teams have developed novel mathematics learning approaches and begun testing their scientific hypotheses about the relationship between EF and mathematics. They have also begun conducting pilot studies of these novel mathematics learning approaches in classrooms to understand different approaches to implementation. As teams begin to share early results from their project's R&D processes, our program is sharing insights from the work as a whole portfolio.

Toward our goal of dramatically improving mathematics outcomes by strengthening the core assets every student has—EF skills—we are excited to share preliminary findings. These findings represent early insights around the intersections of Inclusive R&D, EF skills, conceptual understanding and multi-step problem solving, and equity in mathematics learning. We first introduce core insights that show the overall promise of our approach, then focus on insights that demonstrate how the work comes to life in practice.

EF+Math approaches show promise for improving student learning.

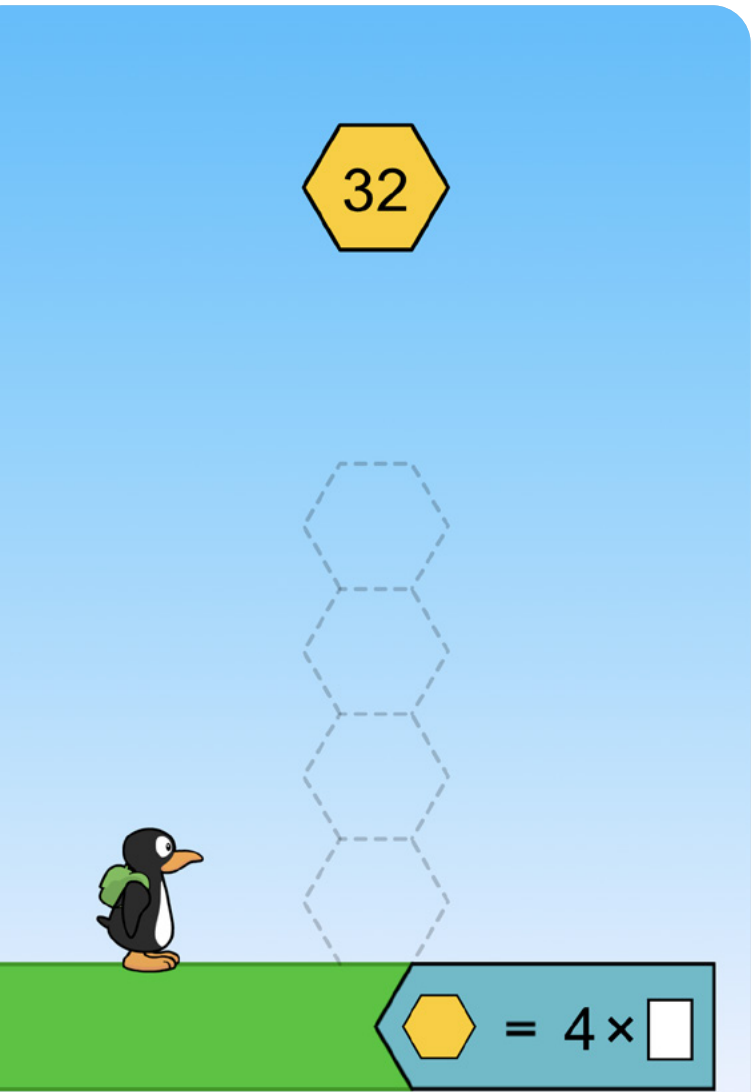
Preliminary evidence from teams that have conducted early implementation studies shows **the positive impact of approaches that simultaneously build EF and mathematical skills** and are designed through our Inclusive R&D process explicitly for Black and Latinx students and students of all races experiencing poverty. While these results are preliminary and from small-scale studies, teams are continuing to gather more evidence through pilot and evaluation studies planned in the upcoming year.

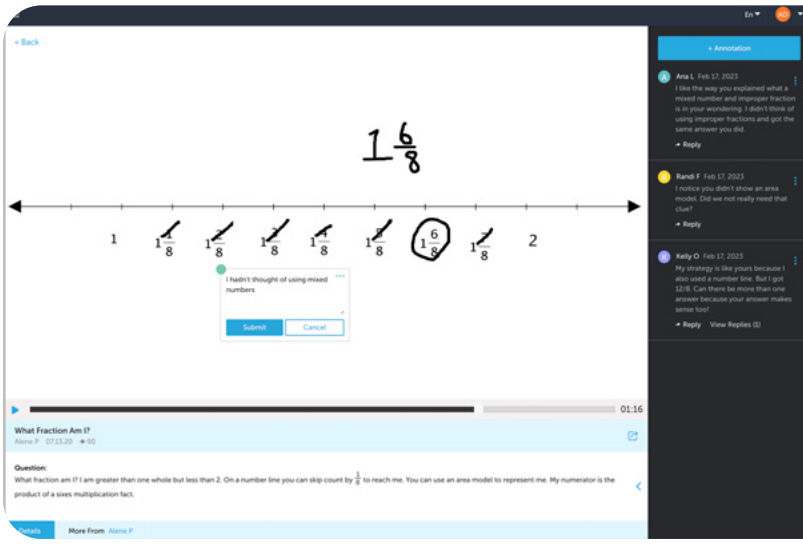
Results from one team—Fraction Ball—show that students are improving their rational number understanding via "embodied learning," a pedagogical approach that connects the body and physical movement to the learning experience. They have demonstrated that when EF skills are combined with embodied mathematics learning activities, students show improvements in their overall rational number understanding. This includes the ability to add fractions and decimals, translate between fractions and decimal representations, and place fractions and decimals on 0 to 1 and 0 to 5 number lines. These represent the range of key grade-level skills for rational number learning that are challenging to teach and learn. In a Spring 2022 study with students in grades four and five, students who participated in Fraction Ball's learning approach showed significant improvement in rational number understanding and arithmetic fact fluency compared to those students who did not engage in Fraction Ball.

Children playing Fraction Ball (Photo: Kenny Lewis)

Another team—MathicSTEAM—offers preliminary results on a small-scale study of their ST Math Fluency+ platform that shows students are improving their working memory, inhibitory control, and mathematics fact fluency. In Fluency+, individual students play mathematics games designed to strengthen and train EF skills on a website that is optimized for smartphones. In a cross-portfolio collaboration, the MathicSTEAM team used the mobile assessment created by the MAT+EF team to assess fourth and fifth grade students from five classrooms on growth in EF skills. Preliminary results from this early study show improved mathematics fact fluency—which is highly predictive of future mathematics achievement—and growth in both working memory and inhibitory control scores (Feng, Buschkuehl, & Jaeggi, 2022; Feng, et al., 2022).

The 'Hex Climber' game from ST Math Fluency+ that focuses on inhibitory control and multiplication





In the CueThinkEF+ platform, students record their thinking via 'Thinklets' and can receive feedback from other students

Research conducted by a third team—CueThinkEF+—suggests that students are improving their problem solving abilities. The CueThinkEF+ team embeds scaffolding for metacognition and other EF skills throughout a problem solving platform; these scaffolds are designed to support the development of students' cognitive flexibility and working memory. Sixth through eighth grade students from one partner district took part in a quasi-experimental study during the 2021-2022 school year. Results from this study suggest that students who utilized the CueThinkEF+ platform improved their scores on problem solving both in terms of understanding and accuracy, compared to students who did not use the CueThinkEF+ platform. Importantly, when data is compared between student demographic groups, differences between the groups' mathematics learning outcomes were narrowed after participation in the CueThinkEF+ learning approach.

When educators and students are involved at every stage of the R&D process, learning approaches are more relevant to the classroom.

Education research and product development that is inclusive and rigorous can lead to transformative student outcomes. Traditional approaches to rigorous research can often favor the voices and perspectives of researchers while attenuating or excluding the voices and perspectives of those who may be most affected by the research (i.e., students, teachers, and communities). We propose that rigorous research is achieved by including the voices of all people impacted in the research process. In fact, rigorous research that is inclusive is what ultimately has the highest impact on students.

By bringing together the educators who have deep knowledge of student learning experiences, the students who experience learning firsthand, and the researchers and developers who have knowledge of math learning science, we are able to implement learning approaches faster and with greater impact in classrooms. New learning approaches are most effectively integrated into curricula when they are aligned to state standards; designed for straightforward implementation; adaptable in response to district, school, and classroom contexts; and feasible for classroom use.

Educators know what works for their students and classrooms. The Fraction Ball team started their work with an idea for a movement-based game that transforms basketball courts into environments for learning fractions. The team began working with mathematics curriculum specialists and school principals from their partner district, and they spent time aligning with district goals and co-designing with educators. Educators raised practical implications of using a basketball court for mathematics learning—like how much time it would take within a lesson to transition to the basketball court and then back to the classroom—and then designed solutions to make transitions more efficient. When the Covid-19 pandemic began during the first year of co-designing the Fraction Ball prototype, educators asked the team to design for multiple contexts, including situations where students physically could not get to the basketball court. Working together, the team created classroom math activities that complemented the Fraction Ball learning approach and reinforced key concepts around rational numbers.

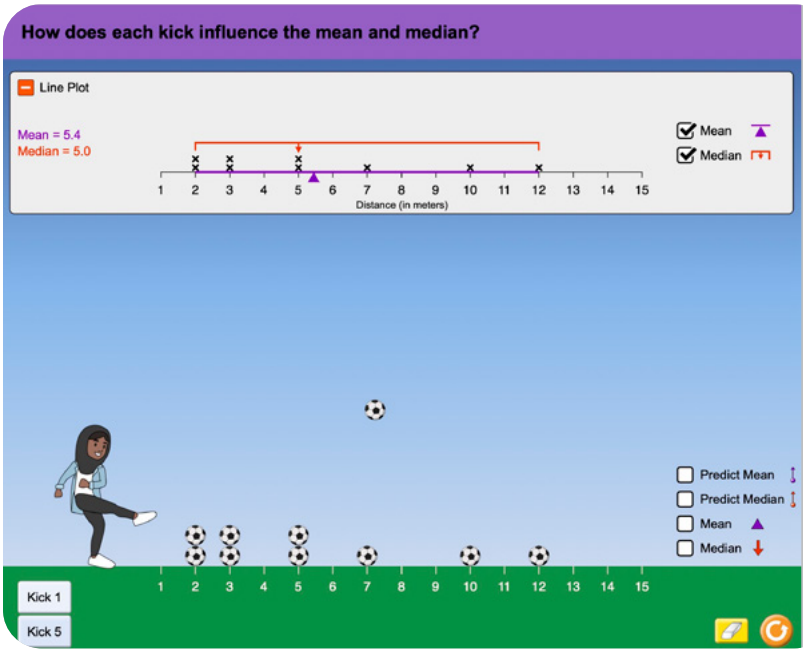
Students who participated in Fraction Ball design activities alongside researchers and developers

Since then, educators continue to lead iterations of the Fraction Ball game. They added the role of "Tracker," where students record shots attempted and shots made. This becomes data for students to analyze and discuss in the classroom to inform strategic approaches the next time they go play on the court. The teachers also pushed the team to differentiate the curricula by grade level so students that experienced Fraction Ball in fourth grade could get a new, more challenging experience in fifth grade. These developments were only possible through the intentional R&D process designed for contributions from educators.

Asking questions, listening, and responding to suggestions helps to build relationships, trust, and a sense of belonging in a new partnership. The Spark Math team began a new partnership with a school district by first listening to teachers' questions and ideas, and from this space of open collaboration, they began developing materials together. Though it took time for everyone to meet, build relationships, and share ideas, the team was ultimately able to develop their mathematics learning approach more quickly because their ideas were well aligned with classroom practice. The team developed four units with 57 lessons, a novel digital learning platform, and associated professional development in a short period of time because of the investment they made initially in building relationships. As this team expands to work with more districts, their relationship-building skills will transfer to new partnerships, such that new districts can move more quickly to co-design and research.

In addition to the educators on our teams from partner school districts, our Inclusive R&D process is guided by our Educator Leadership Council, a diverse group of 17 educators who work at the classroom, school, and district levels. Council members are critical advisors to the EF+Math program staff, expert contributors and co-design partners for the project teams, and integral members of the EF+Math community. Council members provide crucial expertise in mathematics curriculum and deep experience working in districts that serve Black and Latinx students and students of all races experiencing poverty.

The Spark Math statistics unit features an interactive PhET simulation to teach mean and median



As an example of the impact of Educator Leadership Council members on project team designs, the Enlearn team shared that two council members, in addition to other advisors, have had a huge influence on both the focus of the work and the process for its development. The council members changed the design of one of the mathematics activities to include more teacher-friendly features.

Students know what helps them learn. The EF+Math community is designing math learning approaches for Black and Latinx students and students of all races experiencing poverty—and their perspectives play a critical role in our teams' work.

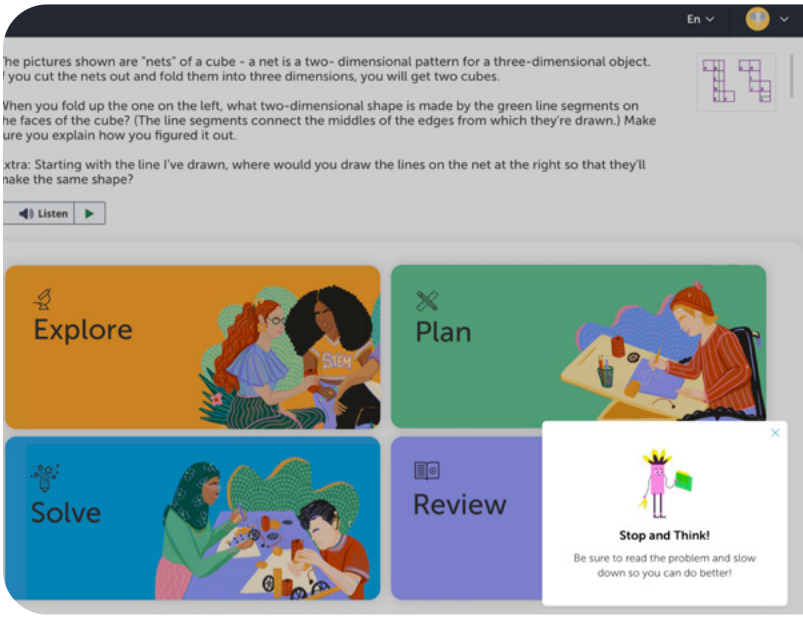
The MathicSTEAM team's co-design students and families worked with curriculum and product designers to create a diverse set of characters embedded throughout the curriculum. The characters elevate the importance of representation and highlight the real-world applications of mathematics. This portion of the MathicSTEAM approach was a direct result of involving students in the design process.

The CueThinkEF+ team intentionally structures every co-design session so that students, educators, researchers, and developers who represent different identities, experiences, and content backgrounds come together to brainstorm, ideate, and design. This format for co-design ensures that the expertise of students and teachers is central to the creation of the CueThinkEF+ product and can influence the researchers who design studies. For example, the CueThinkEF+ team held co-design sessions with students at their schools in the morning before classes started and arranged transportation to ensure all students were able to participate. Together they designed an animated helper for the program that encourages reflection by prompting students to "Stop and Think" during the problem-solving process. Centering student voices led to additional key features that better support students and improved the usability and accessibility of the program.

The Our Mathematical World team included students when designing and improving their mathematics-based storybooks. Students were given different pages of text and asked to draw a picture to accompany the story and record a video explaining their drawings. These drawings became the inspiration for the illustrations used in the books. Students also read early versions of the books, and every student was asked to give feedback. Students' ideas were used when iterating and improving the books to reach their final form.

In addition to classroom resources, student and teacher involvement led to new forms of formative feedback. Ultimately, student learning may be enhanced by empowering students and teachers with timely and accurate feedback; this information provides teachers with actionable data to maximize effectiveness of future instruction and supports students in responding to constructive feedback. Students want constructive

The "Stop and Think" animated helper in the CueThinkEF+ platform



feedback that helps them learn, and teachers want accurate and actionable information about student learning. Thus, in their collaborative work, the Pennesota and CueThinkEF+ teams consulted with students and educators to develop an innovative assessment tool that collects "in the moment" self-report data on students' mind wandering, reflection, and mathematics beliefs. Student input has been critical in creating a tool that does not distract students from problem solving and that is asset based to prevent inadvertently suggesting that changing problem-solving plans or feeling unsure are negative behaviors.

The Enlearn team collaborated with teachers to create meaningful feedback strategies. First, they worked together to develop partial-credit grading strategies that highlight mathematical thinking as a process. While this practice aims to benefit all students, it also has a particular focus on helping English-language learners decide how they want to demonstrate their mathematical knowledge with their current level of English-language proficiency. Second, they collaborated to develop a customized dashboard for problem solving that allows students to see their improvements quickly. The goal is for students to benefit by feeling empowered from the control they have over their own learning and for teachers to benefit by viewing a more accurate representation of student learning.

Student mathematics learning outcomes are improved when executive function skills are strengthened alongside positive student beliefs.

Prior research demonstrates that students benefit from practicing EF skills in the contexts they are intended to be used within (Clements et al., 2016; Diamond & Ling, 2019; Strobach & Karbach, 2016); however, there is still much to uncover about how EF skills and mathematics learning are related. **The early research findings of our R&D teams are revealing new insights about the relationship between EF skills and mathematics learning, which point to opportunities for improved support and assessment of student EF skills.** These exciting results are being used to create more targeted approaches to strengthening and supporting students in managing their attention, thoughts, and emotions.

There are many features of mathematics learning and EF skills that impact the student experience. In their R&D work, the CueThinkEF+ team explored combinations of factors that may be predictors of mathematics learning (Rhodes et al., 2022). They found that students' positive beliefs about mathematics, their working memory scores, prior mathematics knowledge, and opportunities to reflect on learning in mathematics class can contribute to better problem solving. Ongoing analyses aim to understand differences in predictors of problem-solving accuracy and understanding, as these differences may have unique implications for teaching practice.

Students' confidence in their EF skills may be a significant predictor of arithmetic fluency. Students' beliefs that they can strengthen their EF skills may be as important as their actual EF performance. In a preliminary study involving 171 students across two school districts, the MathicSTEAM team found that student ratings of confidence in their EF skills within mathematics contexts were significant predictors of arithmetic fluency performance. Students' inhibitory control and working memory scores were also predictors for mathematics performance in the results of this preliminary analysis.

Further, multiple teams are exploring the associations between EF skills and student performance on problem-solving tasks. Preliminary results suggest that a combination of EF skills may be important for accurate problem solving. The Our Mathematical World team incorporates tasks into their approach that require students to use multiple EF skills to complete them. The team found that student scores on these tasks are significantly correlated with student accuracy on problem-solving tasks. These findings underlie the importance of developing combinations of EF skills within mathematics learning and suggest that integrating such opportunities throughout the EF+Math approaches will benefit students' learning outcomes.

Effectively building students' executive function skills during mathematics learning requires new instructional strategies, tools, and assessments.

Our teams are applying knowledge from existing research to the design of new mathematics learning approaches that incorporate EF skill strengthening and support. These learning approaches need to be supported by curricular resources and assessments that are responsive to changing contexts and needs of students and teachers. Our teams have created such adaptive assessments and tools alongside their learning approaches. This demonstrates the crux of our inclusive R&D processes, where designing tools and assessments simultaneously is essential for using research to drive evidence-based iteration.

Students are strengthening EF skills in practice and learning to use them to have agency over their own learning. When students are solving a problem in a collaborative group setting, they are encouraged to manage turn-taking in order to solicit and engage the perspectives of all members instead of simply running with the first idea. This can lead to further discussion of mathematical ideas, deeper conceptual understanding, and a higher likelihood of reaching productive solution paths. This is an example of using the EF skill of inhibitory control in practice. Many of our teams, such as Mathematical Thinkers Like Me, have embraced the notion of "EF in practice" by intentionally embedding opportunities to develop EF skills such as inhibitory control into problem solving.

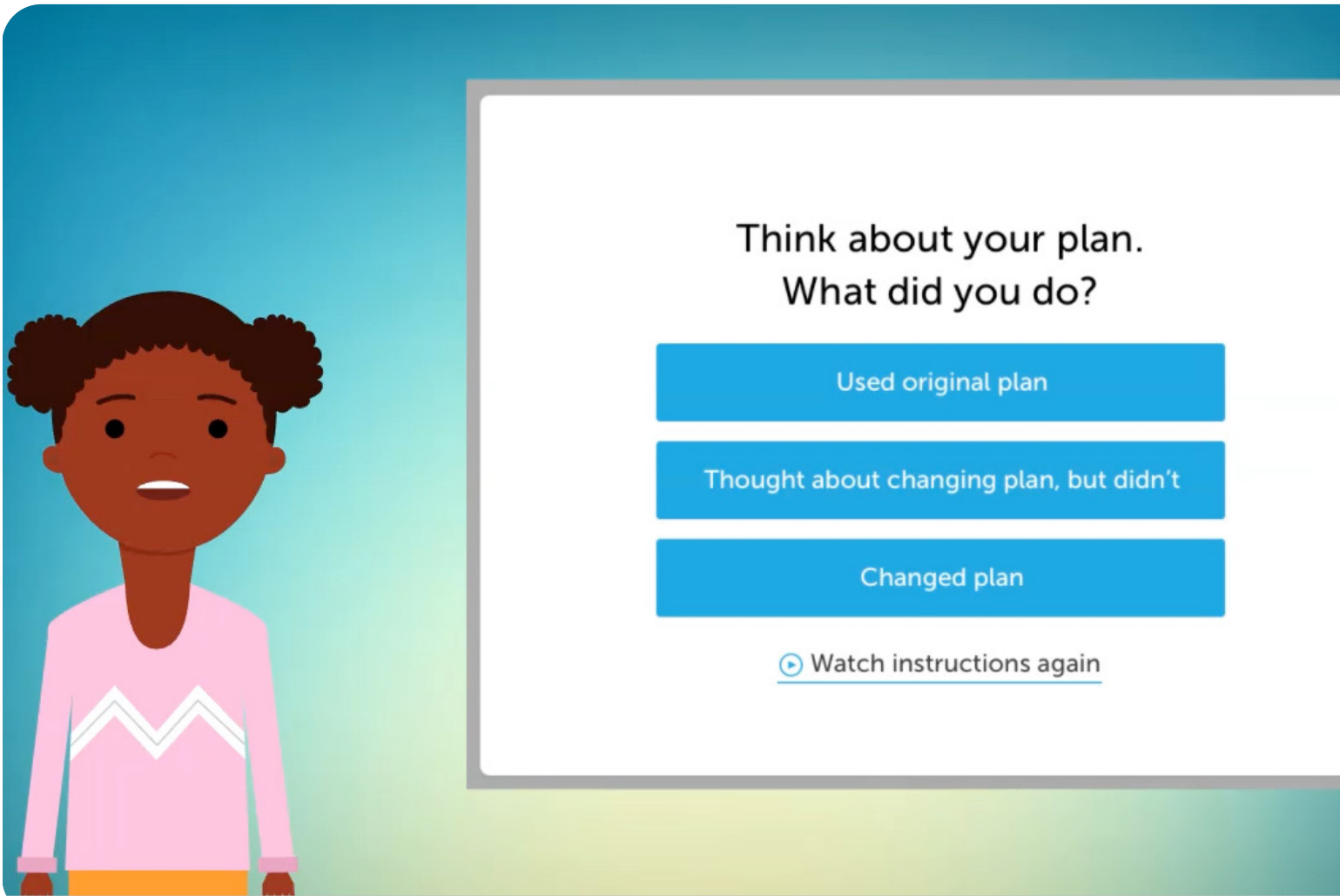
The Enlearn team focuses on encouraging cognitive flexibility development through various mathematics activities that encourage students to cultivate different mindsets, helping them develop multiple perspectives. For example, students are asked to serve as a tutor, with the goal of discovering what strategies other students used to solve a problem. This practice can be used with various content areas, such as number sense and statistics, and seems promising when combined with teacher professional development.

One asset-based approach to building EF skills is to present them as a pathway that creates agency over your own learning. The Spark Math team's approach begins with lessons that explicitly introduce students to their EF skills, followed by opportunities for students to gain relevant practice through games like Equivacards, which integrate multiple EF skills with mathematics learning. The Our Mathematical World team takes a similar approach, introducing EF skills with concrete examples, such as a person directing traffic, intentionally teaching EF skills to students and providing them with opportunities to practice those skills through off-line games (e.g., card games).

Dynamic executive function assessments can support better understanding of students' EF skills in the moment and can guide instructional decisions. A dynamic assessment is one that can measure students' EF skills in the moment; it is responsive, flexible, and adaptive and can provide personalized information. Student experiences and EF skills shift throughout a task, class, and day, given different learning demands. In-the-moment surveys and tasks can assess EF skills during mathematics learning to gather data in a more continuous and authentic way than traditional EF assessments.

The Pennesota team is collaborating with CueThinkEF+ to create an equitable and inclusive assessment that takes an asset-based approach to understanding fluctuating EF skills and math learning experiences. They have validated this assessment using student data inclusive of Black and Latinx students and students of all races experiencing poverty, which promotes more accurate and inclusive assessments in the future (Zhang et al., 2022). Similarly, the MAT+EF team is developing a mobile app that can quickly and easily assess daily fluctuations in students' EF skills and a dashboard that displays these fluctuations to students and educators in positive, asset-based ways.

A pop up created by the Pennesota and CueThinkEF+ teams in the CueThinkEF+ platform that students use to reflect on their problem solving plans



New student-centered tools and assessments emerge when diverse teams focus on designing for equity.

EF+Math teams strive to understand the interactions among student identity and belonging, conceptual understanding and multi-step problem solving in mathematics, and EF skills. Our teams are building on existing research in the field of equity and mathematics alongside educator knowledge and experience of equity practices in mathematics classrooms to develop and research new approaches.

A well-researched component of equity is culturally responsive mathematics pedagogy. Research shows that students are able to better grasp complex mathematical concepts that are situated within relevant cultural contexts (Gutiérrez et al., 2018). Mathematics learning approaches should be used with culturally responsive classroom practices like student-centered and culturally inclusive instruction and relationship building to best help each student succeed. The EF+Math project teams leveraged existing research on culturally responsive pedagogy and created new approaches embedded within their learning materials.

As one example of a culturally responsive practice, students' mathematical understanding improves when students learn from each other (e.g., Hiebert et al., 1997; Ladson-Billings, 1995b). When students work together in intentional ways to learn collaboratively, share their own thinking, drive the problem-solving process, and use their own experiences, they can deepen their understanding.

In the Mathematical Thinkers Like Me team's online environment, Virtual Math Teams, groups of students work together, communicating through dynamic mathematics and text chat. This collaborative environment is designed to foster joint construction of knowledge, make student thinking visible, and be responsive to student interests and experience. Similarly, the CueThinkEF+ platform includes an activity where students view each other's problem-solving processes and annotate them for further development. In particular, CueThinkEF+ is working to understand how the peer review and feedback processes can be impactful for both the student giving and the student receiving feedback. In this way, student thinking is at the center of learning and student understanding drives the conversation.

Celebrating multiple paths of solving problems is another culturally responsive practice that our teams embrace. Enlearn created an algorithm that records all paths through a math problem–solving space, which allows the opportunity for students to demonstrate their knowledge in multiple ways and to celebrate creative and diverse problem-solving approaches. The algorithm is used to provide just-in-time scaffolds and feedback that adapt based on each student's specific and evolving learning needs.

Culturally responsive pedagogy is an ongoing commitment by educators to be attuned to the whole child, which includes knowledge of their home language, their community, their interests, their discomforts, and myriad other nuances that make us human. In mathematics, culturally responsive practices include student collaboration, encouraging multiple solutions, or celebrating student work in problem solving (see for example Ladson-Billings, 1995a; Ladson-Billings 1995b; Ukpokodu, 2011).

They also created a mathematical explanation activity that empowers students to look for errors in the instructor's explanations. This strategy shifts the power dynamic and has the same goal of enabling students to demonstrate their knowledge in many different ways.

Another component of equity related to culturally responsive practices in the mathematics classroom is the family of concepts around student identity and belonging. Prior research shows that identity (Heffernan et al., 2020) and belonging (Matthews et al., 2021) are related to math performance. Moreover, identity and belonging are also related to each other. Intentional strategies to help students build math identity can help to foster a sense of belonging in the math classroom (Aguirre et al., 2013; Elin-Saintine, 2021; Gutiérrez et al., 2018; Matthews et al., 2021). EF+Math teams are creatively applying existing research on identity and belonging to the design of their math learning approaches and studying their impact on student math learning outcomes.

Ensuring students see themselves represented in curricular materials as mathematicians can foster a greater sense of identity in the mathematics classroom and can provide culturally relevant real-world connections. The EF+Math project teams are expanding on representation in mathematics curricular resources in new ways.

The Our Mathematical World team created "math hero" biographies and descriptions of real-world figures and role models of Black and Latinx individuals who use mathematics in their careers (some who are even from students' own local communities, and one who is the author of the storybooks created for use by the Our Mathematical World team). These mathematics heroes counteract the implicit and explicit negative mathematics stereotypes that students may believe about themselves. The Our Mathematical World team also designed a set of storybooks featuring both mathematics problem solving and EF strategies. The characters and storylines in the books were co-designed with students to reflect their diverse experiences, and the books are offered in English and Spanish.

The MathicSTEAM educator, student, and family co-design teams worked with the team's designers to create diverse characters within their materials who grow with students and help make meaningful connections between mathematics and students' cultural and lived experiences. Through these resources, students are able to see characters that look like them who are strong mathematical thinkers and who have agency over their own learning.

A sense of belonging can be cultivated through specifically designed mathematics activities. Mathematics is a way to explore social topics and local issues that students care about. Helping students to see themselves as part of a community helps them develop more agency in their learning. Spark Math offers an entire unit on mathematics and belonging that includes community-building activities, a focus on growth mindset, EF metacognition, and EF skill building. Additionally, teachers and school districts can adapt the Spark Math materials to fit into a more local context, like practicing ratios and percentages with their city's budget or types of local restaurants, allowing students to bring their culture, beliefs, and interests into the classroom.

The Spanish language cover of an Our Mathematical World storybook focused on problem solving

To test and improve these new strategies for developing identity and belonging in mathematics classrooms, teams have advanced assessment methods for measuring student identity and belonging in mathematics. Many existing measurement tools of identity and belonging in mathematics were not designed for use with Black and Latinx students and students of all races experiencing poverty; therefore, assessments can perpetuate deficit mindsets or not accurately capture data regarding these students. Our teams are simultaneously building assessments that center Black and Latinx students and students of all races experiencing poverty alongside their learning approaches.

The Our Mathematical World team is seeking to understand the impact of their work on belonging in mathematics by asking students to "draw a math person" with markers, including skin color tones, and to explain what they drew. This provides a lens into how students see strong mathematical problem solvers and allows teachers and researchers to better understand students' mathematical identities. This assessment is currently being combined with survey questions where students rate how much they agree with the statement "I am a math person" and how others, such as caregivers and teachers, perceive their own mathematical identities.

Many teams are finding that student identity can best be investigated through multiple measures. To meet the need for better student identity measures, teams have begun to use observation and open-ended questions, in addition to standardized measures that are more generalizable, to understand the relationship between student identity and mathematics.

The Mathematical Thinkers Like Me (MLM) team created a MLM Equity Bundle of assessments that combines measures on a variety of subscales, seeking an integrated view of student identity and experience. To a similar end, the CueThinkEF+ team adapted a measure on student mathematics beliefs with more student-friendly and inclusive language and asset-based question framing. The team engaged in rounds of revisions with educators and students to identify language that might perpetuate deficit-based framings of students and replaced it with asset-based language that still addressed the initial construct. Other teams appreciated this new version of the beliefs items—our Enlearn and Pennesota teams are collaborating on a study that uses this adapted scale.

Another way that new assessments emerged when focusing on designing for equity is through the Prather team's work to create improved ways to measure and model classroom context. Instead of designing education innovations for a "typical learner," in which models typically don't account for the many contextual factors that can influence a learner's performance on any given day, this team is developing a dynamic model of individuals and their contexts that can be used to design for a more diverse set of experiences. Pushing the field of cognitive science to move beyond a singular and often white-dominant approach to learning (Prather et al., 2022), this team's work is helping to broaden the notion of how to measure student learning to include contextual factors such as cultural, developmental, and social contexts.

Centering equity from the beginning leads to mindset shifts and a culture of equity and inclusion throughout the process.

EF+Math's first goal was that our teams form communities that are committed to developing their critical racial equity knowledge and cultural fluency and strive to increase collective understanding of the intersections between equity, EF skills, and mathematics. The teams took this call of action to heart, creating equity surveys for internal reflection, equity guidelines and check tools for their products and materials, and professional workshops and training around equity principles. Once an equity-first mindset is established, equity becomes embedded in every aspect of R&D work—including the output products. Over the past two-and-a-half years, EF+Math teams have demonstrated ways to implement equity-first Inclusive R&D in practice, and they have generated new insights on the promise of this approach.

The Educator Leadership Council has been instrumental in leading equity work from the beginning and continues to do so through every step of the process. Early in the program, the Educator Leadership Council helped lead toward a unified understanding of what we mean by equity (see page 7). After year two, the Educator Leadership Council led discussions around an equity check tool created by a council member and a CueThinkEF+ team member, adapted from Matthews et al. (2013), Krall (2018), and Gutiérrez (2009). The council helped all teams evaluate how equitably the mathematics content is portrayed in their materials.

Council members also support individual teams with equity goals. The council members that work with Enlearn helped this team focus on designing activities, interfaces, wording, and prompts for English-language learners. These features were specifically requested by the council members and became one of Enlearn's most concerted efforts to design for a specific underserved group to date. Council members have provided other teams with knowledge and resources around student and teacher beliefs, cultural competence, and student voice.

EF+Math's Educator Leadership Council

One team that centered equity from the start is the Pennesota team. This team made a commitment to an equity-centered approach by considering diversity, equity, and inclusion from multiple angles to ensure it is present in all steps of their process; they also leverage multiple partners in decision making, including students, teachers, and equity advisors.

The Pennesota team brings attention to the need to examine biases within their work, especially in machine learning and artificial intelligence contexts. In publications and presentations, the Pennesota team explicitly calls out algorithmic bias, a situation where an automated system performs in a way that differs based on identity groups (Baker & Hawn, 2022), and articulates strategies to mitigate biases when designing and implementing algorithms. These contributions have the potential to change normative practices in the field. This team actively pursues opportunities for developing individual team members' critical racial equity knowledge through ongoing attendance and participation in symposia and training around implicit bias and other diversity, equity, and inclusion topics. Further, this focus on equity has extended beyond the EF+Math community. Members of the Pennesota team sit on institutional committees and positively influence decisions about equity and access to opportunities within their institutions.

Another way that teams center equity throughout their process is through the use of equity commitments, internal equity surveys, and ongoing equity discussions. Both the Mathematical Thinkers Like Me team and the Our Mathematical World team followed a similar process. With support from Digital Promise, these teams started new partnerships with equity commitments where all members contributed to group agreements around ways they would interact and center equity in their work together. Periodic equity surveys of participating educators, researchers, and developers gathered their input on how well the project teams were meeting the commitments, how well the teams were improving their own cultural competencies, and how well they created an environment that was welcoming to all members. These data were then used to guide team conversations and surface areas of growth that the team could further reflect upon. The creation and administration of these surveys with follow-up discussions demonstrate each team's commitment to using a data-driven approach to examine their own biases and beliefs and to continually push and improve as individuals and as a team in their commitment to equity-centered, inclusive R&D practices.

EF+Math community members collaborating during an early design session

Our *Community*

Our bold pursuit of improved mathematics learning for all students is only possible with community participation—from the teachers and administrators, to the families and community members, to the researchers and product developers—all bringing expertise together to create breakthroughs that advance student learning and increase our understanding of the relationships among EF skills, conceptual understanding and problem solving, and equity.

As our community works together to achieve our long-term goal of dramatically improving mathematics outcomes among Black students, Latinx students, and students of all races experiencing poverty, we have observed transformational changes among the researchers, developers, educators, and institutions who are part of this process. This includes researchers and product developers who center equity in their work and teachers who champion the importance of strengthening EF skills in the classrooms (see **Figure 3**).

Developers and educators from the Spark Math team collaborating at EF+Math's Summer 2022 Convening

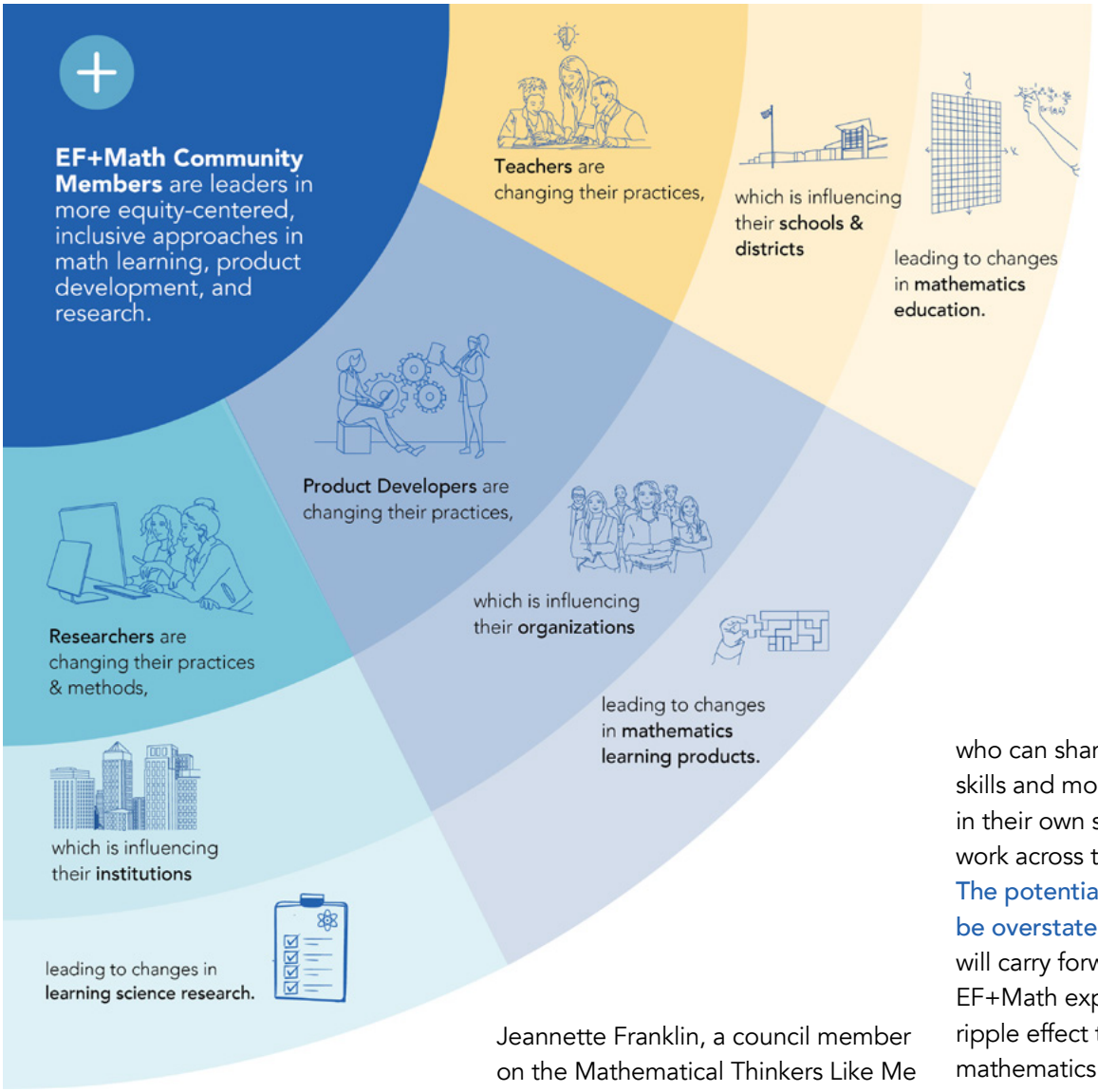
EF+Math's intentional focus on equity-centered and engaged people and equitable process foundations shifted researcher and educator mindsets and advanced racial equity knowledge. This positions EF+Math community members as leaders in driving toward more equity-centered, inclusive approaches in both mathematics learning and education research fields more broadly. We see how the emphasis on developing racial-equity knowledge can expand beyond the focus of a single project team and spread to larger organizations.

One example is how the MathicSTEAM team's commitment to equity-based work was adopted by their larger organization, MIND Research Institute, an organization with a well-established reputation for developing innovative approaches to mathematics learning. Inspired by EF+Math's focus on the development of team members around racial equity knowledge, MathicSTEAM led an initiative to embed equity discussions throughout the entire MIND Research organization. MIND Research Institute's commitment to equity was demonstrated through the development of a formal equity statement that was adopted by the organization as a whole, the launch of an organization-wide diversity, equity, and inclusion advisory council, the creation of an internal professional development module for all employees focused on equity, and the creation of a professional development module for product designers focused on centering Black and Latinx students and students of all races experiencing poverty in product development. They also now have company-wide standards for equity in curriculum design and a curriculum and equity manager position to oversee and develop the equity aspects in their products.

Working with EF+Math not only allowed MIND Research Institute to advance its programming, it also had a profound effect on how the organization itself approaches equity in its operations and product design. While only a portion of the MIND Research Institute participated in the EF+Math process, the entire organization will benefit from the skills and tools acquired through the experience.

Figure 3: The ripple effect of our work

Individuals are shifting their practices and organizations, influencing their respective fields. Collectively, we are shifting the education ecosystem.



When prompted to reflect on how participating in EF+Math's Educator Leadership Council impacted their personal or professional growth, multiple council members described how the program impacted their teaching practice by developing their understanding of EF skills in the math classroom. Additionally, many council members spoke to the role that EF+Math has played in making them better advocates for the Black and Latinx students and students of all races experiencing poverty within their districts.

Jeannette Franklin, a council member on the Mathematical Thinkers Like Me team reflected, "Being a part of the council has allowed me to expand my understanding of what my role is as an educator, and my duty to my students who are mostly students of color. It has also disrupted the level of comfort I have grown accustomed to as a teacher of 20 years. I have begun to wonder about what other work I may become involved with that may have a greater impact."

Beyond leading to more equitable and targeted mathematics learning approaches, our process is helping develop a community of practitioners who can share the importance of EF skills and model equity-centered R&D in their own sphere of influence and work across the education ecosystem. The potential of that network cannot be overstated as each of these experts will carry forward lessons from their EF+Math experience and create a ripple effect that will continue changing mathematics learning programs and processes years to come (see **Figure 3**).

EF+Math's intentional emphasis on equitable processes and equity-centered and engaged people is directly contributing to these longer-term shifts in researcher, developer, and educator mindsets and critical racial equity knowledge. The personal growth and development of those who are part of the EF+Math community will outlast the length of the EF+Math Program and have the potential to impact the work conducted by the people and organizations within our community beyond the life of the program.

Our *Future*

As we complete the third year and move into the fourth year of our five-year R&D cycle, we look forward to evaluating and improving our mathematics learning approaches, sharing our findings, and continuing to expand our community and collective impact. In the first three years of the EF+Math Program and in the midst of a global pandemic, our community laid the foundations for creating truly transformative mathematics learning experiences that affirm the brilliance of Black and Latinx students and students of all races experiencing poverty through Inclusive R&D.

Our R&D teams and their educator partners demonstrate what it means to center equity and inclusion in every aspect of the R&D process. They utilize collective expertise from across educational practice, learning sciences research, and curriculum and product development in the design and iteration of mathematics learning prototypes that strengthen and support students' EF skills. Early results show the potential of EF skills as a lever for improving mathematics learning, while simultaneously uncovering new information about the relationships between mathematics learning and EF skills; additionally, we are generating promising new assessment tools and learning approaches that can not only benefit students now, but can also inform evidence-based design of future curriculum, learning technologies, and teaching strategies. The impact of EF+Math's work is already expanding beyond our community, shifting influential individuals' and organizations' behaviors and actions to be more asset based and equity centered.

Over the next few years, our community will build on this foundation, continuing to iteratively improve our mathematics learning approaches through larger and more rigorous pilot studies being conducted in Spring 2023.

We will share our results and lessons learned from these studies to inform mathematics teaching and learning as well as other equity-centered inclusive R&D efforts. In years four and five of our five-year R&D cycle, we will rigorously evaluate the most promising approaches and establish a through line to scale so that the most effective mathematics learning approaches can contribute to significantly increasing the number of Black and Latinx students and students of all races experiencing poverty in grades 3–8 who are proficient or advanced in math.

As we continue in this process, we issue a call to action. We invite additional partners, including new educator partners, to join us, become part of this growing movement, and actively participate in the continued improvement and evaluation of these promising mathematics learning approaches. We see the promise for students with the adoption of Inclusive R&D practices and look forward to engaging with the broader community of educators, researchers, and developers to collectively advance the field toward Inclusive R&D practices.

It is through the mathematics learning approaches we create, the knowledge we uncover about important relationships between EF skills, mathematics, and equity, and increased awareness of EF skills as essential assets that every student has that we reach our North Star: ensuring every student knows their innate abilities, knows how to use them to take control of their own learning, and is given every opportunity to learn rigorous mathematics.

All students are powerful learners.

Advanced Education Research & Development Fund (AERDF)

Learn more & get involved:
aerdf.org/programs/ef-math/

References

Aguirre, J., Mayfield-Ingram, K., & Martin, D. (2013). *The impact of identity in K–8 mathematics: Rethinking equity-based practices.* National Council of Teachers of Mathematics.

Angevine, C., Cator, K., Liberman, B., Smith, K., & Young, V. (2019). Designing a process for inclusive innovation: A radical commitment to equity. Digital Promise. https://digitalpromise.org/wp-content/uploads/2019/11/Designing-a-Process-for-Inclusive-Innovation.pdf

Baker, R. S., & Hawn, A. (2022). Algorithmic bias in education. *International Journal of Artificial Intelligence in Education*, *32*, 1052–1092 . https://doi.org/10.1007/s40593-021-00285-9

Berry, R. Q. (2008). Access to upper-level mathematics: The stories of African American middle school boys who are successful with school mathematics. *Journal for Research in Mathematics Education*, *39*(5), 464–488.

Bull, R., & Lee, K. (2014). Executive functioning and mathematics achievement. *Child Development Perspectives*, *8*(1), 36–41.

Bustamante, A. S., Begolli, K. N., Alvarez-Vargas, D., Bailey, D. H., & Richland, L. E. (2022). Fraction ball: Playful and physically active fraction and decimal learning. *Journal of Educational Psychology*, *114*(6), 1307–1320. https://doi.org/10.1037/edu0000714

Clements, D. H., Sarama, J., & Germeroth, C. (2016). Learning executive function and early mathematics: Directions of causal relations. *Early Childhood Research Quarterly*, *36*, 79–90.

Diamond, A., & Ling, D. S. (2019). Review of the evidence on, and fundamental questions about, efforts to improve executive functions, including working memory. In J. M. Novick, M. F. Bunting, M. R. Dougherty, & R. W. Engle (Eds.), Cognitive and working memory training: Perspectives from psychology, neuroscience, and human development (pp. 143–431). Oxford University Press. https://doi.org/10.1093/oso/9780199974467.003.0008

Elin-Saintine, T. (2021). *Racial inequity in mathematics education: Exploring academic identity as a sense of belonging*. Emerald Group Publishing.

Feng, Y., Buschkuehl, M., Grose, G., Jaeggi, S. M., Ramani, G., Ghil, E., & DePascale, M. (2022, June 1–3). *Testing the benefits of an embedded math fluency and executive function intervention in children* [Paper presentation]. Annual Mathematical Cognition and Learning Society Conference, Antwerp, Belgium.

Feng, Y., Buschkuehl, M., & Jaeggi, S. (2022, October 7). *Examining The Structure of Math-related Executive Function Beliefs in Children* [Paper presentation]. International Group for Understanding Arithmetic, Numerical Cognition, and Language (IGUANA), Digital Symposium.

Gutiérrez, R. (2009). Framing equity: Helping students "play the game" and "change the game." *Teaching for Excellence and Equity in Mathematics*, *1*(1), 1–13.

Gutiérrez, R., Goffney, I., & Boston, M. (Eds.). (2018). *Annual Perspectives In Mathematics Education 2018: Rehumanizing Mathematics For Black, Indigenous, And Latinx Students.* National Council of Teachers of Mathematics.

Heffernan, K., Peterson, S., Kaplan, A., & Newton, K. J. (2020). Intervening in student identity in mathematics education: An attempt to increase motivation to learn mathematics. *International Electronic Journal of Mathematics Education*, *15*(3). https://files.eric.ed.gov/fulltext/EJ1259005.pdf

Hiebert, J., Carpenter, T. P., Fennema, E., Fuson, K. C., Wearne, D., Murray, H., Olivier, A., & Human, P. (1997). *Making sense: Teaching and learning mathematics with understanding*. Portsmouth, NH: Heinemann.

Krall, G. (2018). *Necessary conditions: A self study guide for teachers and coaches on improving math discussions*. Stenhouse Publishers.

Ladson-Billings, G. (1995a). But that's just good teaching! The case for culturally relevant pedagogy. *Theory into Practice*, *34*(3), 159–165. https://doi.org/10.1080/00405849509543675

Ladson-Billings, G. (1995b). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal*, *32*(3), 465–491. https://doi.org/10.3102/00028312032003465

Martin, D., Gholson, M., & Leonard, J. (2011). Mathematics as gatekeeper: Power and privilege in the production of knowledge. *The Journal of Urban Mathematics Education*, *3*(2), 12-24.

Martin, D. B. (2012). Learning mathematics while Black. *Educational Foundations*, *26*, 47–66.

Martin, D. B., Gholson, M. L., & Leonard, J. (2010). Mathematics as gatekeeper: Power and privilege in the production of knowledge. The Journal of Urban Mathematics Education, *3*(2), 12–24.

Matthews, J., Gray, D. L., Lachaud, Q., McElveen, T., Chen, X., Victor, T., Okai, E., Boomhower, K., Wu, J., & Cha, E. (2021, October 15). Belonging-centered instruction: An observational approach toward establishing inclusive mathematics classrooms. https://doi.org/10.31219/osf.io/n7bv2

Matthews, L. E., Jones, S. M., & Parker, Y. A. (2013). Advancing a framework for culturally relevant, cognitively demanding mathematics tasks. In J. Leonard & D. Martin (Eds.), *The brilliance of Black children in mathematics: Beyond the numbers and toward a new discourse* (pp.123–150). Information Age Publishing.

Merkley, R., Matusz, P. J., & Scerif, G. (2018). The control of selective attention and emerging mathematical cognition: Beyond unidirectional influences. In A. Henik & W. Fias (Eds.), Heterogeneity of function in numerical cognition (pp. 111–126). Academic Press. https://doi.org/10.1016/B978-0-12-811529-9.00006-6

Miller-Cotto, D., & Byrnes, J. P. (2020). What's the best way to characterize the relationship between working memory and achievement?: An initial examination of competing theories. *Journal of Educational Psychology*, *112*(5), 1074–1084.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

National Council of Teachers of Mathematics (2014). *Principles to actions: ensuring mathematical success for all*. Reston, VA: National Council of Teachers of Mathematics.

National Research Council. (2001). *Adding It Up: Helping Children Learn Mathematics*. National Academy Press. https://doi.org/10.17226/9822

Rhodes, S., Bryck, R., Gutierrez de Blume, A., & DePiro, A. (2022, March 3–5). *An Exploratory Study of Factors Influencing Mathematics Problem Solving* [Paper presentation]. Annual Conference of the Research Council on Mathematics Learning, Grapevine, TX, United States.

Strobach, T., & Karbach, J. (Eds.). (2016). *Cognitive training: An overview of features and applications*. Springer.

Ukpokodu, O. N. (2011). How do I teach mathematics in a culturally responsive way? Identifying empowering teaching practices. *Multicultural Education*, *19*, 47–56.

U.S. Department of Education, National Center for Education Statistics. (2019). *Early Childhood Longitudinal Study, Kindergarten Class of 2010–11 (ECLS-K: 2011) Public-Use Kindergarten–Fifth Grade Data File and Electronic Codebook* (NCES 2019-050) [Data set]. Early Childhood Longitudinal Studies (ECLS) Program. https://nces.ed.gov/ecls/dataproducts.asp

Zhang, J., Andres, J. M. A. L., Hutt, S., Baker, R. S., Ocumpaugh, J., Nasiar, N., Mills, C., Brooks, J., Sethuaman, S., & Young, T. (2022). Using machine learning to detect SMART model cognitive operations in mathematical problem-solving process. *Journal of Educational Data Mining*, *14*(3), 76–108.