



Request for Information for Advanced Education Research & Development Programs  
Draft Program Description: Program B

## **Improving Mathematical Understanding, Application and Related Mindsets**

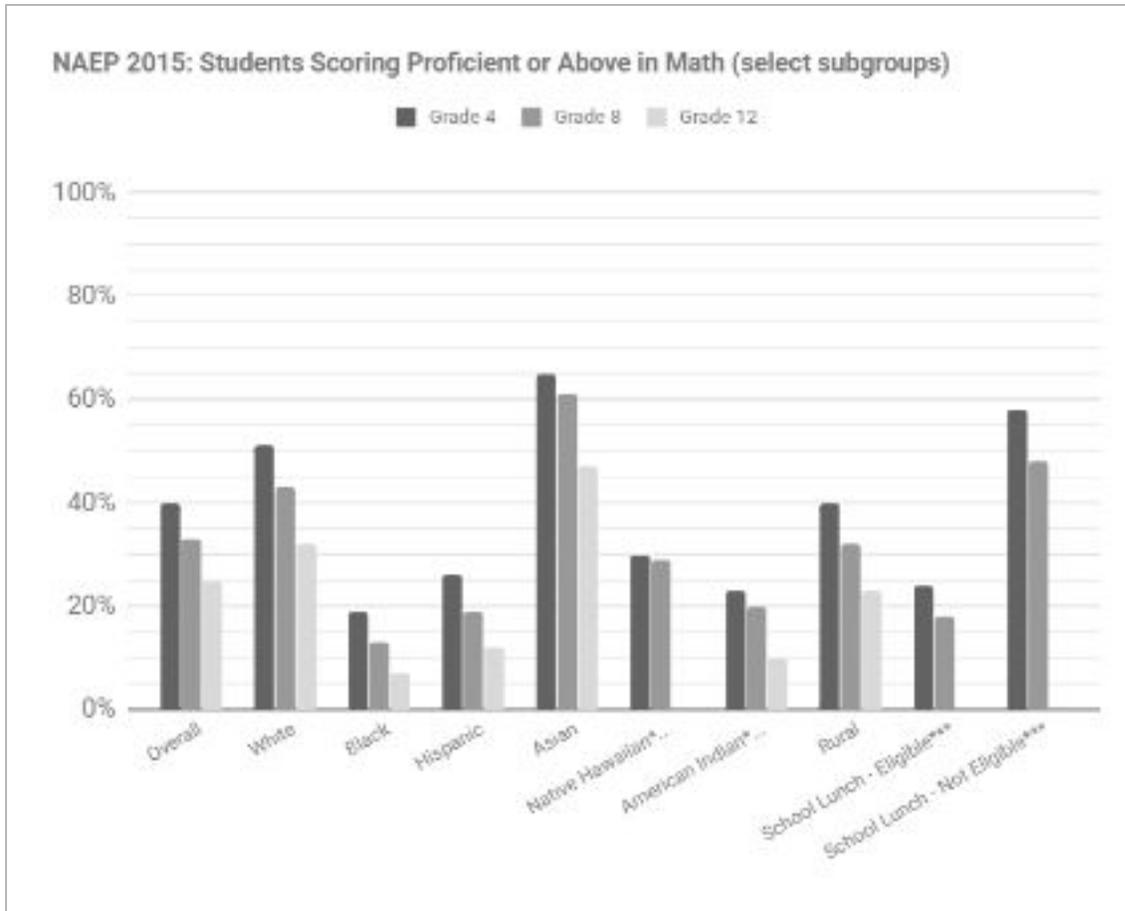
This document is part of the Request for Information for Advanced Education Research & Development Programs announced by the Chan Zuckerberg Initiative and the Bill & Melinda Gates Foundation. Full details on this RFI, including submission information, can be found at [www.chanzuckerberg.com](http://www.chanzuckerberg.com) and [k12education.gatesfoundation.org](http://k12education.gatesfoundation.org).

We are requesting information for innovative strategies to help address the above challenge within the US context (solutions from non-US contexts with applicability in the US are also welcome).

On the following pages, we are providing a concept description for the math program. This is, indeed, a *draft* description - because we intend, through this RFI, to refine this program idea, or add to it. We expect it will change, perhaps dramatically, based on your input.

## Problem

Mathematical proficiency is a prerequisite for students to meet current high school graduation requirements. It also is critical in unlocking opportunity for students to pursue a wide range of post secondary pathways and STEM careers. Currently, performance in mathematics is far below standards for many demographic groups by the middle grades. It continues to decrease through high school, creating barriers to graduation and postsecondary pathways early in life.



\* Subgroup is reported as "Native Hawaiian / Other Pacific Islander", abbreviated for space

\*\* Subgroup is reported as "American Indian / Alaska Native", abbreviated for space

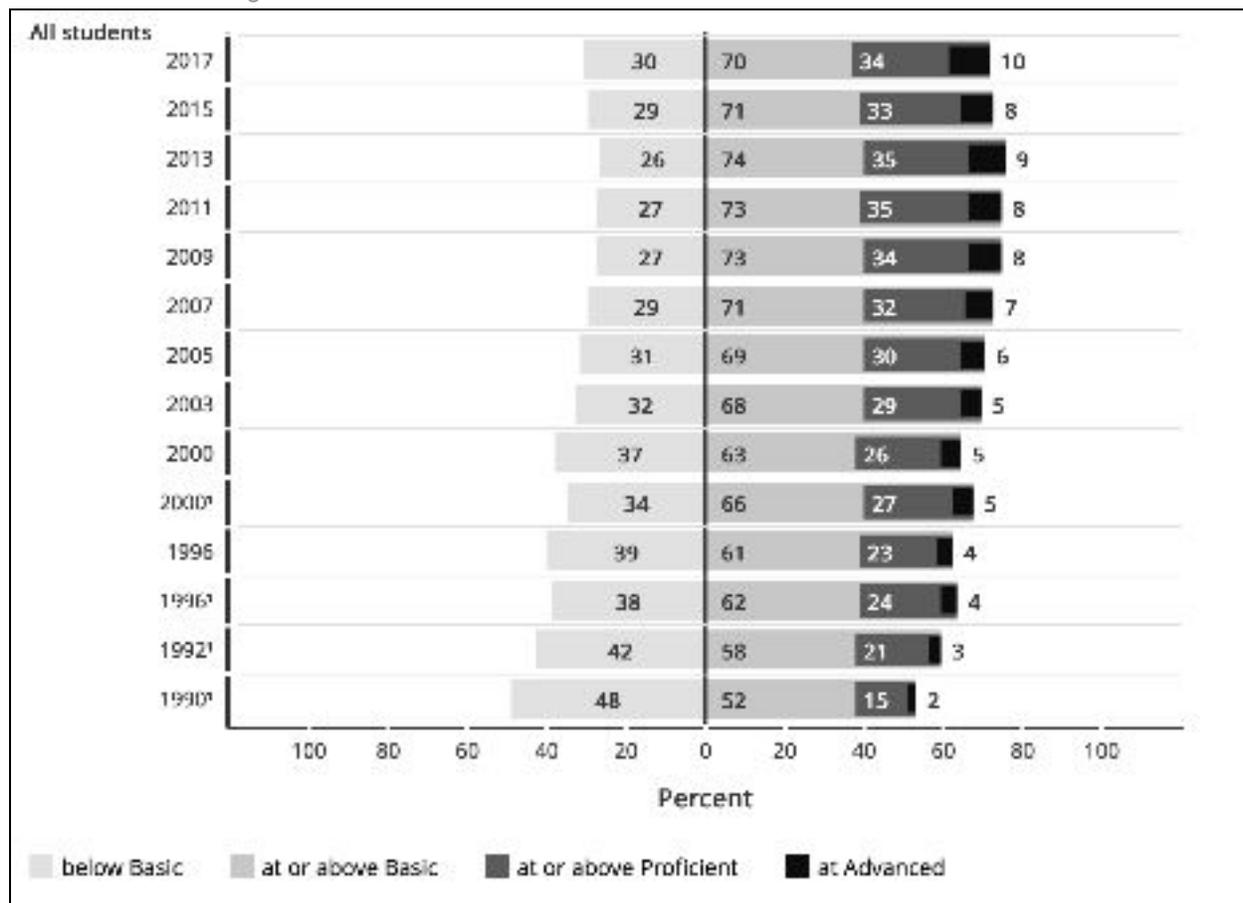
\*\*\* Subgroups are reported as "Eligibility for National School Lunch Program (NSLP)", abbreviated for space

Note: data unavailable for some Grade 12 subgroups; 2017 data not presented as Grade 12 was not tested in 2017

Source: <https://www.nationsreportcard.gov/>

Many worthy efforts are underway to improve the teaching and learning of mathematics, through higher standards, well-designed curricula, teacher professional development and targeted student interventions. There has been incremental improvement in many states and districts over the last 15 years. However, Black, Latino, and low-income students often remain significantly underserved by today's approaches, and student performance in all subgroups remains well below NAEP proficiency standards by the middle grades.

Trends in NAEP 8th grade mathematics achievement-level results



Source: <https://www.nationsreportcard.gov/ndecore/xplore/NDE>

Addressing individual student needs in mathematics is challenging in classrooms where students enter at a wide range of proficiency levels. Each day, many middle and high school teachers see 150 or more students, whose proficiency can range from significantly behind to beyond grade-level standards. Regardless of the starting point, providing support to every student to meet grade-level requirements in a single year, using traditional instructional models, is an almost impossible challenge. Yet, today, this is what teachers are expected to do. While supplemental 1:1 or small group instruction can help, providing every student with sufficient time and support from an expert tutor is not feasible, given the cost and logistics required.

There are promising field-developed approaches emerging that help teachers to address individual student needs by mirroring the same personalized approaches used by the best 1:1 tutors—especially when combined with expert, well-supported teachers in an active learning environment. Highly personalized learning experiences and tools have the potential to analyze student responses to understand barriers to student learning, provide immediate feedback, and apply immediate and effective remediation to students when needed. When well designed, these experiences and tools can help

teachers identify groups of students with common misconceptions and target small group instruction as well as allow students in a classroom to learn at their own pace or explore differentially related knowledge or skills. Computer-assisted approaches to providing these experiences offer the potential of affordable scale and accelerated iteration and improvement.

Up to this point, computer-assisted approaches to providing such experiences, such as intelligent tutoring systems, have yet to provide the levels of improvement that would allow all students to reach proficiency in mathematics, and are currently not accessible in terms of cost and ease of use to a large population of teachers and students. A recent meta-analysis of intelligent tutoring systems' effectiveness indicated that current approaches yield a median effect size of 0.66 standard deviations, equivalent to about a boost in scores from the 50th percentile to the 75th percentiles (Kulick & Fletcher, 2016). Developing teaching and learning systems that greatly exceed this effectiveness requires a re-examination of how learning environments, and the tools that are commonly used in them, are currently designed and developed. Existing systems have yet to take full advantage of current knowledge of how the brain works, including the cognitive, metacognitive and social emotional dispositions that drive learning, and were not designed to integrate seamlessly with teacher-guided instruction and other classroom-based learning flows.

We hypothesize that at least a two standard deviation improvement (raising students from the 50th to the 98th percentile) in mathematical proficiency with a focus on conceptual understanding, could be an attainable goal when combining effective teacher-directed instructional strategies with better designed personalized-learning strategies, platforms and tools. This level of improvement would ensure that most students attain a level of proficiency in mathematics required to successfully access and pursue STEM-focused pathways in secondary and post-secondary education, and into the workforce.

In this RFI we seek to understand and identify (1) the latest innovations and, most important, future possibilities for learning strategies and tools that support teachers to produce a full standard deviation or more in improved math achievement with a focus on deep conceptual understanding and (2) their most effective potential use in classrooms as part of an overall, integrated instructional model. Current constraints on the ability to improve learning outcomes at these levels could be due to a variety of complex and inter-related factors. Some of the areas we believe require more exploration include, but are not limited to:

**Tools and resources that support teachers to personalize the learning experience for all type of student learning needs:** Whether working with 25 students or 200 each day, teachers need current, accurate, and easily understood information about what each student knows and is able to do to help with a complex array of math learning issues across a classroom. Can we design highly personalized and scalable experiences that perform at a much higher level than existing intelligent tutoring or

adaptive systems and that integrate well within instructional models and learning environments, encouraging more effective teacher-student, peer-to-peer interactions and collaborative learning?

**Focus on the “whole student”** - Creating successful lifelong learners who deeply understand and can apply mathematics requires a broader focus than solely academic skill development. Can we design highly scalable evidence-based approaches and measures that support both teachers and learners in a variety of ways to alleviate math anxiety, improve executive functioning, and foster learning mindsets (growth mindsets, sense of belonging, sense of purpose), academic perseverance, metacognition, student agency, and more?

**Awareness of cognitive and affective state** - The best teachers intuitively integrate a wide array of academic and non-academic data in helping learners succeed, far more than even the most intelligent tutoring systems typically rely on. Can we create better measures of engagement, attention, and comprehension to improve the effectiveness of teaching that can be incorporated in highly scalable strategies and tools by enabling them to measure student cognitive and affective states, in ways that protect student privacy and provide actionable information to teachers?

**Continuous improvement of teaching and learning experiences, resources and tools** - Educational resources are typically static and change little, if at all, over time. Can we use systematic evidence-driven improvement cycles and tools to continuously optimize the effectiveness of each learning experience for each student including improving the teaching, instructional resources, and tools used with each student?

**Ease and affordability of authoring content** - Existing learning management and support systems often make modifying or authoring content difficult. Can we create tools to allow educators and other education experts to create, modify, and share content while providing guidance on effective evidence-based approaches?

**Engaging, relevant user experiences** - One common problem with many current mathematics instructional systems and tools is a lack of rich, varied, and engaging content that promotes conceptual understanding and higher-order problem solving. Is it possible to incorporate evidence-grounded combinations of engaging content and interfaces such as virtual assistants, games, simulations, VR, AR, or comics to give students a variety of opportunities to apply mathematical concepts to relevant problems, at low cost? Can we create highly scalable active learning experiences tied to real-world benefits, and also promote conceptual learning, retention and transfer of math concepts while helping students develop stronger identities of self-efficacy in mathematics?

**Informing, not automating** - Teachers often report that it is hard to understand and track what students are doing across the digital and non-digital resources and tools at their disposal, hence it is hard to coordinate in-class instruction with students' digital experience. Dashboards are a common, but not satisfactory solution. How can we

provide information to teachers and students in ways that are easily understood, useful, and enhance their teaching and learning?

**Measuring what students know and can do** - Current evidence-gathering about learning based on assessments provides relatively infrequent summative information about students' progress, not detailed information in real time to help teachers understand each student's learning needs, both procedural and conceptual. Frameworks like Evidence-Centered Design (ECD) provide a compelling method for structuring the evidence-gathering rationale and process, but are not currently integrated into most assessment approaches. Using ECD or other evidence-gathering frameworks that incorporate conceptual as well as procedural mastery, how can gaps between instructional and assessment capabilities of different resources and tools be bridged?

### **Assessing potential for impact**

We hope to use the input from this RFI to inform the design of a measurement framework for a potential R&D program focused on dramatically improving mathematics achievement, particularly for learners that are far below grade level. We are ultimately seeking comprehensive approaches to innovative mathematics learning instruction that incorporate technology, learning science, and good learning measurement with effective teaching and learning practices in ways that are easy for teachers and students to use, and that generate dramatically better student learning outcomes on grade-level standards. Some of the potential target measures we may include are described below. However, we are also interested in new ideas for innovative approaches to measuring the efficacy and scalability of proposed projects. Please submit those as part of your response.

Specific attributes of outcomes of successful approaches could include:

- Dramatic improvement in student motivation, engagement, and mindsets, along with reduction in math anxiety.
- Dramatic improvement in math proficiency on grade level standards that incorporate measures of rigor, cognitive challenge (Depth of Knowledge levels 3-4) and the ability to communicate ideas using the language of mathematics (Standards of Mathematics Practice 3&6) for all sub-groups, particularly students in racial and socio-economic groups scoring below the 50th percentile in NAEP achievement scores.
- Positive changes in teacher mindsets and levels of math anxiety, particularly for elementary and middle school teachers tasked with teaching mathematics who do not have specialized math certifications.
- Demonstrated efficacy in a wide range of student learning environments, with different levels of available teacher coaching and other resources.
- Affordable cost to implement - below current market pricing for existing solutions and attainable at a variety of per-student funding levels.
- Ease of integration into standard math (grades 3-12) courses and instructional environments in a range of typical and underserved settings.

- Enhanced precision in measurement of student learning at the level of specific knowledge component or sub-standard.
- Speed, precision and ease of use of feedback and guidance on remediation approaches for teachers.
- Models for peer collaboration that build social competencies and contribute measurably to motivation, engagement and learning in mathematics.

### **Request for Information**

We anticipate that existing research & development is underway in specific capability areas that could contribute to the end goals of this program. We are requesting information about the current state-of-the-art for the topic areas below and bold ideas for potential advancement in these capabilities over 10 years that could have application in creating effective learning experiences in math.

Submissions should address one or more topic areas.

### **Potential Topic Areas**

Possible topic areas within this program may include, but are not limited to the following areas

- New and novel pedagogical approaches – Seeking optimum ways for conveying math concepts to students within technology-enhanced learning environments, and the optimum methods for teachers to work with these tools within the classroom.
- Performance-based measures and analytics – New and novel methods for measuring mastery, both procedural and conceptual, and providing immediate, actionable feedback for students and teachers.
- Mindset/executive function Interventions – Strategies to improve, harness, or take into account student mindsets and executive functioning skills within highly scalable strategies and tools. Includes demonstrating academic impacts for success, and support tools/services for teachers to make evidence actionable.
- Math achievement expectations and engagement - Approaches to increasing confidence, motivation, engagement, and effort when pursuing challenging math learning experiences
- Intelligent tutoring systems – Highly personalized, engaging math tutoring systems that take a whole-student approach and provide actionable information to students and teachers.
- Artificial intelligence – Includes algorithms to improve personalization and/or real-time feedback to the student, virtual assistant technologies to improve engagement and interactivity with students, and support tools for teachers.
- Technology-enhanced content – Innovative and engaging content to integrate in an intelligent tutoring system including, but not limited to, Augmented Reality, (AR), Virtual Reality (VR), games, comics, lecture, laboratories, etc., together with tools to connect teachers into these activities and student progress within them.

- Neuroscience-based measures – Scalable technologies to provide measures of engagement, attention, and comprehension, delivering actionable information to students and teachers while safeguarding student privacy.
- Privacy – Identification of possible privacy implications and strategies for ensuring the privacy and security of student information.
- Other – Innovations that may provide large-scale student and teacher performance enhancement in conjunction with personalized-learning strategies, platforms and tools.