CADRE Brief

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Broadening Participation—Making STEM Learning Relevant and Rigorous for All Students

THE PROBLEM

K–12 schools play a pivotal role in fostering STEM literacy. STEM classes can help students hone the analytic and problem-solving prowess they need to face complex challenges at home, at work, and in the world. STEM skills and knowledge can prepare students to pursue a wide range of rewarding careers. Over a lifetime, a solid STEM education can ensure that people crack the code of complex STEM issues in headlines and on ballots and make wise decisions. Yet while all students need a strong STEM education, far too many students graduate from high school without a solid foundation of STEM skills and knowledge. This is especially true for youth of color, youth from low-income communities, youth with disabilities, youth who are English learners, and young women—all of whom are underrepresented in the STEM workforce.[1,2, 3]

Over a lifetime, a solid STEM education can ensure that people crack the code of complex STEM issues in headlines and on ballots and make wise decisions.

National Assessment of Educational Progress (NAEP) and ACT findings, along with a series of reports—including the National Research Council's *Successful K-12 STEM Education*[4] and related *STEM Smart* briefs[5]—reveal serious deficits in our system of STEM education. For example, strong math skills are key to STEM learning and college and career success in and beyond STEM fields. Yet 2015 National Assessment of Educational Progress (NAEP) data reveals that few Grade 8 English learners (6%), students with disabilities (8%), black students (13%), students from low-income families (18%), Hispanic students (19%), Native American/Alaska Native students (20%), and female students (33%) scored at or above proficient in mathematics.[6] In 2014, few Black (14%), Native American (20%), and Hispanic (29%) ACT-tested high school graduates met the Mathematics College Readiness Benchmark.[7]

Relatively few Grade 8 white students score at or above proficient in mathematics (43% in 2015, 2% fewer than in 2013[8]). Yet the significantly and persistently lower scores of students from underrepresented groups spotlight critical *STEM learning opportunity gaps*. An analysis of U.S. Department of Education Office of Civil Rights (OCR) civil rights data from every U.S. public school reveals that many students cannot access high-quality STEM instruction. OCR found that compared to 81% Asian American and 71% white high school students, 47% of American Indian/Alaska Native, 57% Black/African American, 63% students with disabilities, and 65% English language learner high school students could access the full range of math and science courses (Algebra I, geometry, Algebra II, calculus, biology, chemistry, physics) in their schools.[9] OCR also found that African American students were over “four times as likely, and Latino students twice as likely, as their white peers to attend schools where more than 20% or more of their teachers have not yet met all state certification and licensing requirements.”[10]

The factors that contribute to opportunity gaps go far beyond the need to improve access to high-quality STEM learning experiences. To ensure all students receive a sound STEM education, the U.S. must also address deeply rooted and widely acknowledged inequities in its system of STEM education, including the following:

- Teachers are not receiving the intensive, ongoing support they need to provide excellent, equitable STEM instruction.
- There is a poor fit between traditional STEM instructional strategies and the needs of many students, resulting in ineffective learning experiences and environments for many students.
- There is a lack of culturally relevant STEM learning experiences, resulting in many students from underrepresented groups feeling that “STEM’s not for me.”
- Low expectations and stereotype threat—in which the prospect of being judged based upon negative stereotypes places extra stress on students—are prevalent for students from underrepresented groups and undermine their academic performance.
- Many students from underrepresented groups lack access to high-quality out-of-school time (OST) STEM learning opportunities that can enhance their in-school learning and spark their interest in STEM careers.

These complex and pervasive challenges will not respond to quick fixes. They require investment in the design and systematic testing of effective interventions that can address issues of prejudice, uproot inequities, and strengthen the entire STEM learning infrastructure.

With its portfolio of broadening participation initiatives that seek to remove barriers to STEM education and create pathways to STEM careers for members of underrepresented groups, the National Science Foundation (NSF) is making these investments. Across the portfolio, researchers—often in close collaboration with practitioners—are identifying and disseminating promising approaches to ensuring that all students receive an outstanding STEM education.

PROMISING APPROACHES TO BROADENING PARTICIPATION

Each initiative in the NSF’s broadening participation portfolio focuses on enhancing STEM learning for one or more underrepresented group: students from low-income families, black students, Latino/a students, students with disabilities, Native American/Alaska Native students, English learners, and young women. Yet the strategies that initiatives are using to address the challenges outlined above also have the potential to strengthen our overall system of STEM education and benefit all students. Descriptions of a few of the NSF-funded initiatives that are seeking to enhance the relevance, rigor, and equity of STEM education follow.

SUSTAINING NEEDED CHANGES THROUGH INSTITUTIONALLY SUPPORTED PROFESSIONAL DEVELOPMENT

> "Buy-in from school and district leaders is crucial when you're designing and studying professional development to support teachers in changing their practice. It can be difficult to obtain, but it is key. Some districts have told me, 'Researchers come in, they want data, we give it to them, and then they leave. We don't hear anything more from them.' When you operate that way, you lose the trust of administrators and that will reduce their commitment and support for teachers working in a different way. You need to listen to what the district needs and identify ways to help." **M. Alejandra Sorto (Texas State University), PI of Mathematics Instruction for English Language Learners**

Researchers have found that providing high-quality instruction and curriculum is one of several approaches that benefit diverse populations of students.[11] Ongoing, high-quality professional development—particularly intensive, job-embedded strategies such as coaching and communities of practice—is seen as key to supporting teachers in implementing effective strategies and instructional resources to meet the needs of diverse populations of students. Many NSF Discovery Research PreK–12 (DRK–12) initiatives that focus on broadening participation are examining models that engage STEM educators in modifying their instruction to address the needs of students of color, students with disabilities, students who are English learners, students from low-income communities, and female students. Indeed, professional development is central to all of the other promising approaches this brief describes.

Some initiatives are beginning to look beyond building teacher capacity to engaging school and district administrators. An important goal of this work is to ensure teachers have the long-term, institutionally-backed support they need—from supervisors, principals, and superintendents, as well as coaches and professional developers—to sustain changes in instruction, curriculum, and learning environments to meet the needs of students from underrepresented groups. As just one vital cog in a complex system, teachers who seek to change their practice without buy-in from school and district leaders can face insuperable obstacles in implementing new, more equitable teaching strategies. The example below spotlights one DRK-12 initiative that is in the vanguard of clarifying the supports needed to not just support, but to sustain changes in STEM instruction.

Middle School Mathematics and the Institutional Setting of Teaching

(PI: Kara Jackson, University of Washington; co-PI: Paul Cobb, Vanderbilt University)

This two-phase study is examining the question, "***What does it take to support mathematics teachers' development of ambitious and equitable instructional practices on a large scale***?" Since 2007, researchers have collaborated with middle school mathematics teachers, school leaders, and district leaders in four urban districts in the U.S. that have limited financial resources, large proportions of students from high-need communities, and an urgent need to enhance mathematics education for black students and English Language Learners. The PIs are testing a theory of action for instructional improvement in a large school district that has five components: (1) a coherent instructional system for ambitious and equitable instruction that encompasses both formal and job-embedded teacher professional development; (2) teacher networks; (3) mathematics coaches' practices in providing job-embedded support for teachers' learning; (4) school leaders' practices as instructional leaders in mathematics; and (5) district leaders' practices in supporting the development of school-level capacity for instructional improvement. Findings from this research, which the PIs have begun to disseminate, have significant potential to inform the design of all STEM education reform initiatives that seek to use professional development to improve outcomes for students from underrepresented groups.

Learn more about this initiative: http://go.edc.org/MISTWebsite

ADDRESSING THE NEEDS OF EACH STUDENT: UNIVERSAL DESIGN FOR LEARNING (UDL)

> "How can we provide safe and supportive STEM learning environments that make *each student* feel confident that she or he will be successful? Start by defining the learning experience's goal, and then identify many ways to help students reach that goal. The first level of support is basic access features, such as making text read-aloud, providing text in large fonts, and translating text. Those supports are much easier to provide in a technology-based environment, and they need to be in place so you can engage students who need those supports in deeper learning. Next, think about scaffolds to support executive functions and self-regulation to help all students work their way through a deep inquiry experience. For example, if you know that self-monitoring and questioning is difficult for some students, structure support to guide them through the process—such as building in sentence starters. Finally, build in varied ways for students to show their understanding, such as audio recording their responses or making a video." **Samantha Daley (Center of Applied Special Technology, Inc.), PI of Inquiry Primed**

Universal Design for Learning (UDL) gives teachers tools and strategies that help them focus on the needs and strengths of each student and make learning more accessible, engaging, and motivating for all students. The core of the approach is offering ***students multiple ways to engage in learning, represent their learning, and act upon and express their learning*** (http://go.edc.org/UDLGuidelines). Drawing upon UDL and technology[12] can enhance the STEM learning of all students—and significantly benefit students with disabilities—by removing access barriers and providing key supports that enable students to dive deeply into learning content and demonstrate their knowledge.[13]

Sheldon Berman, Chair of the Center for Applied Special Technology's (CAST) Board of Directors noted in a November 2015 article in *School Administrator*, "Just as universal design revolutionized architectural design, UDL is revolutionizing curricular design and instructional planning by providing the academic curb cuts and other pathways that facilitate access to core concepts and skills development by all students."[14] Despite its strengths, UDL is not in use in all STEM classrooms. Several DRK–12 projects, such as the one described below, are advancing knowledge of how to build teachers' capacity to use UDL to provide high-quality STEM instruction—with a special focus on students with disabilities and students who are members of underrepresented groups.

Teacher Professional Development for Technology-enhanced Inquiry to Foster Students' 21st Century Learning

(PI: Kathleen Koenig, University of Cincinnati; co-PI: Casey Hord, Purdue University)

Drawing on UDL and inquiry approaches, the PIs are designing learning modules—featuring embedded assessments and Web-based apps—that will foster seventh graders' deep science content knowledge and acquisition of scientific reasoning and 21st century skills. The overarching goal is to give teachers the tools they need to successfully engage all students in high-quality STEM learning—with a special emphasis on meeting the needs of students who are members of underrepresented groups and students who have disabilities. The PIs are studying the effectiveness of the modules on teacher practice and student learning in an urban district in which over 20% of the students have specific learning disabilities. Findings from the project have the potential to guide future efforts to broaden participation by enhancing the STEM learning experiences and outcomes of diverse populations of students in urban districts.

Learn more about this initiative: http://go.edc.org/UDL21stCentury

INCREASING THE RELEVANCE OF STEM LEARNING: STUDENTS AS PARTNERS

> "If you're serious about broadening participation, you should always talk to students because you have to understand their cultural experience and perspectives. What are the prior experiences they bring, and that you can leverage to make the learning more relevant, real, and connected to what they already know? For PIs and educators, this requires a shift in thinking. You need to recognize that while you have expertise in STEM content and the model you are using, the students that you want to engage have equally vital expertise to contribute from past learning and social and cultural experience. They are experts in that, and they can help ensure learning and interventions are relevant, motivating, and engender persistence. When we engage students as active partners in designing programs and in learning, we take both of our expertise and make something really powerful and effective." **Jakita Thomas (Spelman College), PI of Supporting Computational Algorithmic Thinking (SCAT)**

The UDL approach described above is one form of student-centered learning that can help make STEM learning more relevant and effective. Other forms use strategies that draw upon students as partners. For example, in ***youth participatory design processes***, educators engage students in creating instructional resources[15]—building STEM skills and knowledge, while ensuring that resources respond to students' interests, experiences, and needs. Engaging youth as ***partners in STEM education research***, including studies of youth motivation in STEM,[16] can give researchers vital insights and empower youth. ***Place-based learning*** engages youth, and taps their expertise, by weaving their daily lives, cultures, and communities into in-depth explorations of science, mathematics, social studies, and other subjects.[17,18]

Both pre-service and in-service teacher training need to have a greater emphasis on student-centered learning, including integrating new research on strategies to effectively reach and teach students from underrepresented groups and draw upon their background knowledge. In the initiative described below, a researcher-practitioner team used a "reciprocal noticing" process to enhance mathematics learning for English language learners by actively engaging students in clarifying their prior knowledge, enabling the teacher to scaffold learning accordingly and "design tasks to promote student sense making."[19]

Reciprocal Noticing: Latino/a Students and Teachers Constructing Common Resources in Mathematics (PI: Higinio Dominguez, Michigan State University)

Working with teachers in Texas and Michigan, the PI is investigating the role that reciprocal noticing, "an interpersonal process that allows two people to notice each other's ideas," can play in creating equitable mathematics learning environments for Latino/Latina, African American, recent immigrants, and English learners. By testing multiple reciprocal noticing strategies—including instructional interviews with students and actively engaging students as partners in instruction—the study is providing new insights into how to support better interactions between teachers and Latino/a students in mathematics classrooms. Findings have significant implications for designing pre-service and in-service teacher education that prepares teachers to create intellectually engaging and responsive mathematics learning environments for diverse populations of students. The team published early findings from the work in an article that received the 2015 Linking Research and Practice Outstanding Publication Award from the National Council of Teachers of Mathematics, and the PI will draw upon final findings to develop videos to integrate into methods courses for preservice elementary teachers.

Learn more about this initiative: http://go.edc.org/ReciprocalNoticing

RAISING EXPECTATIONS AND ADDRESSING STEREOTYPE THREAT

> "It is important for all of us—STEM teachers, education leaders, researchers—to move past the deficit mindset that is prevalent in education. Whether we are designing interventions, conducting STEM education research, or directly engaging students in STEM explorations, we need to bring the mindset that ALL students are capable learners. We must address the deficit mindset to make progress in better meeting the needs of all learners, and that means engaging all students in productive struggle. We need to support students in using strategies that make sense to them as they tackle tasks just outside their current understandings, place the responsibility of thinking on students, build their critical thinking skills, and help them develop perseverance." **Jessica Hunt (University of Texas-Austin), PI of Fraction Activities and Assessments for Conceptual Teaching (FAACT) for Students with Learning Disabilities**

Research has confirmed that low expectations of underrepresented students—rooted in assumptions and stereotypes about their abilities—reduces the quality of instruction for students,[20] negatively impacts learning outcomes including college completion[21] and weakens schools.[22] Stereotype threat can have equally potent and harmful effects on students' STEM learning outcomes. In stereotype threat, the prospect of being judged based upon—or reinforcing—negative stereotypes about their intellectual ability places extra stress on students with disabilities, female students, students of color, and English language learners and undermines their learning and academic performance.[23]

To achieve goals to broaden underrepresented students' participation in STEM, pre-service and in-service teacher development programs,[24,25] as well as systemic change efforts at the school and district level, must focus on addressing these two issues. The DRK-12 project described below offers an example of one professional development model that engages general and special educators in jointly designing challenging mathematics learning experiences for students with and without disabilities.

Supporting Staff Developers in the Implementation of Professional Development Programs to Improve Mathematics Education for Students with Disabilities
(PI: Babette Moeller, EDC; co-PIs: Lynn Goldsmith, Amy Brodesky, EDC)
This study examined strategies to support staff developers in implementing two professional development programs—*Math for All* and *Addressing Accessibility in Mathematics*—that engage special educators and mathematics educators in working together to make mathematics lessons accessible to students with disabilities without undermining the academic rigor of the lessons. Both programs are co-facilitated by mathematics and special education staff developers, who support special educators and mathematics educators in jointly analyzing student work (in videos or on paper) and build their capacity to observe students, identify students' strengths and needs, and build specific strategies to help students reach learning goals. Participants work on planning lessons that they carry out in their classrooms. Findings from this study can serve to inform efforts to scale up professional development programs while maintaining fidelity of implementation.
Learn more about this initiative: http://go.edc.org/SupportingStaffDevelopers

ENSURING EQUITABLE ACCESS TO OUTSTANDING INFORMAL STEM LEARNING

> "We need to sustain a strong ecosystem of high-quality, interrelated STEM learning opportunities, and we need to expand access to that ecosystem. For example, if a young person has a great STEM experience in an afterschool program, what does she do next? How does she broker more experiences for herself? How can afterschool programs, communities, and schools help broker more experiences for her? Some programs have this as a goal. For example, 4-H, Boys and Girls clubs, and Girls Inc. have robust cultures of working in local

> communities to connect young people with other STEM learning opportunities. Discovery Science Center in Orange County ran a program for parents simultaneously with the kids' summer camp so that families could share their science learning and talk about it at home. Community Science Workshop Network in California runs in low-income communities and does an excellent job engaging children and youth in STEM-rich making and tinkering. Their mobile units go right out to the schools and pick up kids. Access is key." **Vera Michalchik, Director of Evaluation and Research, Stanford University Office of the Vice Provost for Teaching and Learning**

Out-of-school time (OST) STEM learning experiences can "serve as the critical bridges that tie together school, family, mentors, and workforce preparation to create a network of access and opportunity for youth from underrepresented and under-resourced backgrounds to experience STEM success." [26] In a 2015 National Research Council (NRC) report, the Committee on Successful Out-of-School STEM Learning noted that informal STEM learning can "contribute to young people's interest in and understanding of STEM, connect young people to caring adults who serve as role models, and reduce the achievement gap between young people from low-income and high-income families." [27] In addition, many high-quality OST STEM programs foster informed citizenship by empowering underrepresented young people to engage in problem-solving, collect and analyze data, and take action related to issues that they care about and that affect their communities.[28, 29,30]

Yet for OST programs to realize their potential to broaden participation in STEM, more young people must be able to access high-quality OST STEM programs[31]—such as the DRK-12 OST project described below—and the "OST STEM ecosystem" must be assessed and strengthened to better serve all young people.[32,33] In addition, more research must be done to better understand how to effectively link learning between and among informal and formal STEM learning environments to maximize benefits for students.

Supporting Computational Algorithmic Thinking (SCAT)
(PI: Jakita Thomas, Spelman College)
As the PI examines how girls develop computational thinking and problem solving skills, she is engaging middle-school African-American girls in rich informal learning focused on game design to increase their confidence in STEM, give them a solid foundation in Computational Algorithmic Thinking (CAT), and spark their interest in computer science careers. Over three years, the girls participate in two-week intensive summer camp sessions; complete workshops in which they use programming languages to build their games to submit to national game design competitions; and go on field trips that show them how employees in different industries use CAT. They also receive guidance in game design and STEM careers from experts in CAT and undergraduate computer science majors at Spelman College. Findings indicate that the program is benefiting participating girls' in-school learning—through both increased knowledge/skills and confidence—and that they are beginning to see computer science as a possible career.
Learn more about this initiative: http://go.edc.org/SCAT

SUMMARY

The following five approaches show promise to remove barriers to the successful STEM learning of underrepresented students and broaden their participation in STEM. These same approaches are likely to enhance the STEM learning of all students.

1) Advance and sustain needed changes in STEM education through intensive, job-embedded professional development supported by school and district leaders.

2) Discard ineffective "one-size-fits-all" STEM instructional strategies and draw on UDL and

technology to tailor instruction to address the needs and strengths of each student.

3) Make STEM learning more relevant and engaging to students by actively involving them as partners in research, design, and instruction.

4) Have high expectations for diverse population of students and address invisible barriers to their successful STEM learning, such as bias and stereotype threat.

5) Work to expand access to high-quality OST learning experiences—including access to mentors and role models—and identify ways to connect in-school and OST STEM learning to maximize the benefits of both for students.

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