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RESEARCH

Wealth, Equity, and STEM: Increasing STEM Access and Participation of Students from Economically Disadvantaged Backgrounds

This summary is based upon work supported by the National Science Foundation under Grant No. 1818635. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Background: What is the Issue?

K–12 and postsecondary students from economically disadvantaged backgrounds face institutional and/or structural barriers to accessing science, technology, engineering, and mathematics (STEM) education and pursuing STEM careers. Students from economically disadvantaged families often leave college because of financial constraints, attend schools without adequate science labs and materials, and/or lack access to STEM mentors with similar backgrounds (Rideout & Katz, 2016).

The COVID-19 pandemic has disproportionately affected low-income students, further intensifying pre-existing conditions such as financial hardship, lack of access to computers and internet, and decreased availability of out-of-school STEM programming (Marcos, 2020; Rideout & Katz, 2016). To create an equitable and diverse STEM workforce, it is imperative that institutions identify and dismantle barriers so that students from economically disadvantaged backgrounds can access increased opportunities and resources to succeed in STEM (Chelberg & Bosman, 2019; Dika et al., 2015).

Purpose of this Brief

This research brief is primarily intended for individuals who work within institutions and systems to broaden participation in STEM, as well as for individuals who wish to support these efforts such as researchers and funders. It summarizes evidence-based strategies that increase STEM access and participation for elementary to postsecondary students facing economic hardships. It also includes a discussion on heightened barriers caused by the COVID-19 pandemic. We feature the perspective of the NSF INCLUDES Design and Development Launch Pilot (DDLP) Project *The Alabama Alliance for an Inclusive Middle Grades Computer Science Preparation through Makerspaces in the Alabama Black Belt Region*, which adopts a hands-on approach to engaging middle school students in higher-level computer science courses. The brief also contains a list of eight active NSF INCLUDES awards that explicitly focus on serving students from economically disadvantaged backgrounds.

Definitions of Terms

Researchers' definition of "low-income," "low socioeconomic status," and "economic disadvantage" vary greatly when referring to students' ability to access STEM pathways; these terms are often used interchangeably. Throughout this brief, we use "economically disadvantaged background" as an umbrella term that describes students' difficulty accessing STEM education and careers due to family income, educational attainment, and subjective perceptions of social status and class. Below are some common indicators used in the education field and in the research we cite in this brief:

Income — There are a range of indicators of poverty. Researchers often use federal poverty guidelines when identifying students from low-income backgrounds. However, a large percentage of the population that experiences financial duress does not meet these guidelines and thus measures of poverty are often percentages above 100% of the federal guidelines. For example, a student is eligible for free and reduced-price school meals if their family income is between 130% and 185% of the poverty line (Food Research & Action Center); this might be sufficient as an indicator of poverty in some regions and not in others, depending on the cost of living. In higher education research, eligibility for a Pell Grant is a common indicator for identifying students from low-income backgrounds.

Economic Disadvantage and Socioeconomic Status — "encompasses not only income but also…quality of life attributes and opportunities afforded to people within a society" (APA, 2019). Because these terms are difficult to measure, education researchers often use indicators such as eligibility for the Free or Reduced-Price Meal program, parental educational attainment, or household income above the federal poverty line to identify socioeconomic status.

The Imperative: Removing Barriers for Students from Economically Disadvantaged Backgrounds

K-12 and Higher Education Context

With public K-12 school funding tied to local property taxes and ever-increasing college costs, students from economically disadvantaged backgrounds face serious obstacles to educational attainment. For example, children who attend K-12 schools where a majority of students qualify for free or reduced-price lunch are less likely to have teachers who receive the resources they need to teach math, are less likely to experience hands-on science activities, and have less access to science labs and materials (Kena et al., 2015).

At the postsecondary level, students from low-income backgrounds leave STEM fields at a higher rate than their counterparts (Chen, 2013). In 2019, only 9% of students from low-income high schools (defined as schools where at least 50% of the entire student population is eligible for free or reduced-price lunch) earned a STEM degree within six years of high school graduation, as compared to 18% from high schools where less than 25% of the population is eligible for free or reduced-price lunch (National Student Clearinghouse, 2020). Further illustrating the connection between economic disadvantage and race/ethnicity, only 10% of students from high-minority high schools (where at least 40% of the students are Black or Hispanic) earned a STEM degree within six years of high school graduation, as compared to 17% from low-minority schools.

Supporting students from economically disadvantaged backgrounds through postsecondary education is crucial; postsecondary education creates greater access to work that provides a higher standard of living, not only through higher wages but also through employee benefits like healthcare and paid time off (Georgetown University Center on Education and the Workforce, 2016). When broken down by occupation, college graduates with STEM degrees have some of the highest average annual earnings (National Science Board, 2020; Oreopoulos et al., 2013). In 2017, the median annual salary for science and engineering (S&E) occupations was $85,390, more than double the median for all U.S. workers (National Science Board, 2020). Over the next decade, STEM jobs “are projected to grow faster, provide greater earning potential, and produce lower rates of unemployment than non-STEM jobs” (Rozek et al., 2019, p. 1553). Even when students don’t obtain a degree in a STEM field, STEM courses provide “useful skills, such as numerical and computer literacy, which are broadly marketable across a variety of careers” (Rozek et al., 2019, p. 1553).

Racism and Poverty

Race and ethnicity are critical factors in discussing economic disadvantage. On average, 39% of children live in households that are low-income (defined as twice the federal poverty threshold). When disaggregated by race, it is clear that poverty in the U.S. is correlated to systemic racism. Below are the percentages of children living in low-income families by race/ethnicity:

- **59% of Black children**
- **59% of American Indian children**
- **56% of Hispanic children**
- **27% of Asian children**
- **27% of White children**

(National Center for Children in Poverty, 2021).

Access to Technology

Access to necessary technologies is an issue common to both K-12 and higher education. Although there is significant progress towards better computer access in schools, digital inequities still exist in terms of access to home computers and internet service (Arias, 2020; Callahan, 2019; Judge et al., 2006). According to the Federal Communications Commission, more than 21 million Americans do not have internet service capable of providing a broadband connection for streaming high-definition videos with download speeds of at least 25 megabytes/second (Lourenco & Tasimi, 2020). Nearly half of all households with income less than $30,000 per year have no internet connection. Black and Hispanic households lag behind their White counterparts in internet implementation even after controlling for income (Lourenco & Tasimi, 2020). This issue spans all education levels and these inequities became particularly acute during the COVID-19 pandemic.

In the past year, compulsory remote learning due to the pandemic exacerbated the need for adequate computer and internet access for many low-income households (Lai & Widmar, 2020). Virtual learning relies heavily on digital technology that many low-income families cannot access. Low-income families were likely to be less equipped with the number of technological devices that adequately support children in online learning. Even in households with multiple devices, thousands of students had low bandwidth at home unable to support the speed required to effectively participate in school and work activities (Beaunoyer et al., 2020). Lack of adequate technological access at home led to disruption in online education, learning loss, and students drastically falling behind in their academic achievement during this crisis (Lourenco & Tasimi, 2020). COVID-19 has intensified inequity in education access and participation (Marcos, 2020).

Successful Strategies for Increasing STEM Access and Participation of Students from Economically Disadvantaged Backgrounds

To address disparities in access to STEM education and careers, we present six evidence-based strategies to improve access and participation for students from economically disadvantaged backgrounds. These strategies are drawn from studies on efforts that nurture students to pursue STEM education, and the next section presents relevant evidence for each strategy. The six strategies are:

- **Providing adequate financial resources.**
- **Offering one-on-one mentoring support.**
- **Engaging in motivating and culturally responsive teaching approaches.**
- **Providing adequate technology and technology support.**
- **Offering out-of-school STEM programming.**
- **Focusing on targeted student recruitment strategies.**

Providing Adequate Financial Resources

Providing adequate financial resources is a strategy focused on the financial supports needed for low-income students to access and complete postsecondary education or training. Finances affect students in myriad ways. Lack of financial resources can limit opportunities for students in many ways, affecting access to college and whether a student can attend college at all (Long & Riley, 2007; Mitchell et al., 2018; Rincon & George-Jackson, 2016); students' choices about where to attend college (Heller, 2002; Koricich et al., 2018); and whether students can complete college. Many students drop out of college due to financial constraints such as the inability to afford tuition and other living expenses (Cabrera & Fries-Britt, 2008; McDermott et al., 2018; Pratt et al., 2019; Seidman, 2005). Finally, a lack of financial resources can impede student engagement, progression, and completion (Chaplot et al., 2015; De Broucker, 2005; National Student Clearinghouse Research Center, 2020; Pratt et al., 2019).

Louisiana State University's (LSU) Scholarships for Science, Technology, Engineering, and Mathematics (S-STEM) project, funded by NSF provides financial support to academically talented students from economically disadvantaged backgrounds through stipends and tuition waivers (Wilson et al., 2012). Providing financial aid to economically disadvantaged students increased the retention rates of students in STEM disciplines through graduation (Wilson et al., 2012). At the time of the study, the retention rate of the economically disadvantaged cohort with extra support through the S-STEM project was at 94%, a stark contrast to the 34% six-year graduation rate (between 1998 and 2003) for LSU STEM majors not enrolled in the program (Wilson et al., 2012).

Sufficient financial support, especially need-based financial aid targeting economically disadvantaged students, is associated with increased retention for students majoring in STEM fields (Chen & Kelly, 2013; Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce Pipeline, 2010). Estrada et al. (2016) encouraged federal and private agencies to provide adequate and sustainable financial resources to economically disadvantaged STEM students to reduce the financial burden that hinders them from fully engaging in their studies. Beyond financial assistance, a holistic approach that caters to other student needs has the potential to create sustainable improvements for students from economically disadvantaged backgrounds pursuing STEM education.

S-STEM Program Highlight

The National Science Foundation (NSF) Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) program supports low-income academically talented students pursuing degrees in STEM disciplines who have demonstrated unmet financial need. The low-income status is defined within local institutional contexts by the Institutional Office of Financial Aid or equivalent.

The program offers financial support in the form of scholarships (at least 60% of the budget) as well as other activities such as internships, research experiences, and conference attendance (National Science Foundation Scholarships in Science, Technology, Engineering, and Mathematics, 2021).

Engaging in Motivating and Culturally Responsive Teaching Approaches

A fundamental premise in both motivation and Culturally Responsive and Relevant Education (CRRE) research is that learning should be meaningful (Kumar et al., 2018). In meaningful learning, teachers facilitate classroom activities that draw connections between the curriculum and students' real-world experiences (Lee et al., 2019). Weaving the elements of culturally responsive education into classroom activities can create learning environments that treasure cultural diversity, motivate students, and promote participation (Kumar et al., 2018). Boykin (2014) and Hurley et al. (2009) found that when teachers immersed culturally regarded themes into the curriculum and teaching practices, economically disadvantaged Black students in elementary and middle school performed at higher levels in mathematics, science, and language arts.

In another study, students and teachers from two economically disadvantaged urban middle schools in Portland, Oregon participated in the Science in the Learning Gardens (SciLG) project (Williams et al., 2018). The garden-based project centered on activities and instructional practices that are motivationally and culturally responsive to students' needs and experiences (Williams et al., 2018). The project provided the opportunity for students to engage in meaningful, relatable, competent, and autonomous science learning tasks. Findings suggest that garden-based activities were positively related to enhanced student engagement and learning of science and fostered ongoing interest in science pursuit (Williams et al., 2018).

ALCSE-INCLUDES, an NSF INCLUDES funded project explicitly focused on economically disadvantaged communities also used responsive and collaborative project-based learning approach to engage students in STEM activities (see callout box on the right for more details).

NSF INCLUDES Network Highlight: Hands-on Approach to CS Learning

The ALCSE-INCLUDES (www.csmakers.org) is a partnership designed to provide access to authentic Computer Science (CS) education at the middle grades through a stand-alone pilot CS course called "CS Makers." By "authentic," we mean that students learn concepts central to CS such as algorithms, coding, and robotics as opposed to routine tasks such as keyboarding and the use of editing software.

The CS Makers course is specifically designed to encourage students from economically disadvantaged communities to gain foundational and rigorous CS experiences. The course curriculum was created by the project's CS faculty in alignment with the Alabama course of Study on Digital Literacy and Computer Science and is taught in Makerspaces where students convene to collaboratively and experientially explore a broad range of CS topics using a student-centric Project-Based Learning (PBL) framework. CS Makers provides multiple professional development activities for participating teachers to ensure their readiness to facilitate the use of CS Makers curriculum in their school's Makerspace.

The ALCSE-INCLUDES partnership launched the CS Makers course in the 2018-2019 school year in four middle schools of the socio-economically disadvantaged Black Belt region of the state of Alabama. Since then, over 225 students have taken the course with impressive signs of broader impacts: approximately 75% of the enrollment was from communities historically underrepresented in computing, and nearly half of the students were young women. Project assessment reveals that students viewed the CS Makers course as leading to acquisition of CS concepts, and more likely than other courses to help them develop teamwork, persistence, and taking initiative and responsibility in the problem-solving process.

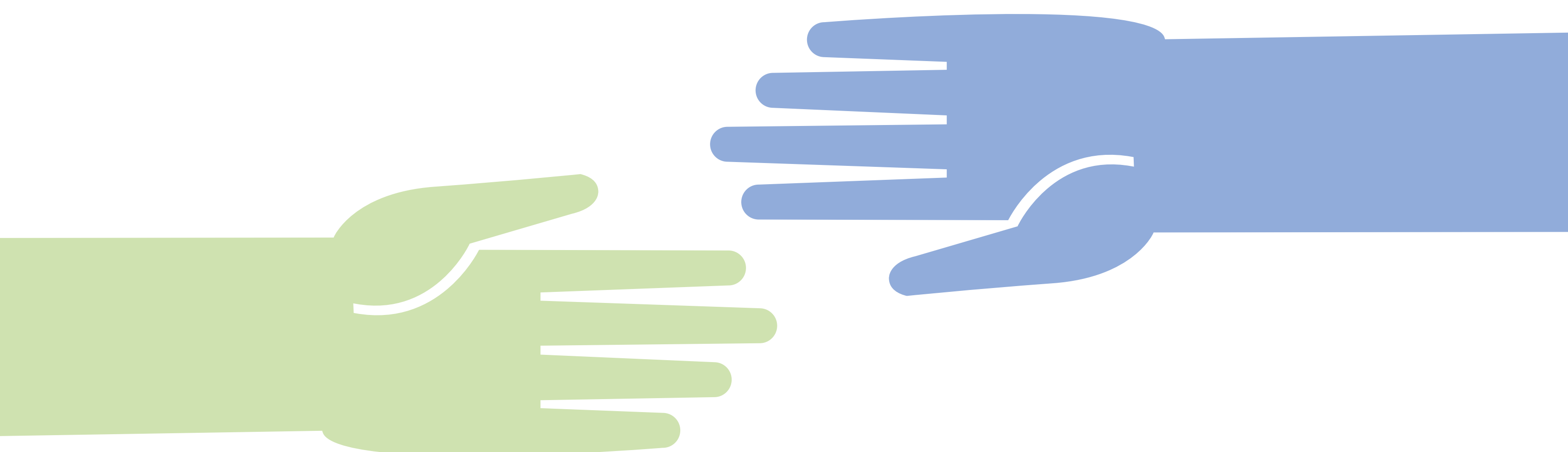
The CS Makers course was designed to be a pathway builder that provides students with the basic knowledge needed to pursue the high school-level Exploring Computer Science and AP Computer Science Principles courses, where available. The state of Alabama recently passed legislation mandating that all middle and high schools in Alabama offer a CS course by the 2022-23 school year. This act will ensure that equitable access to preparatory CS experiences such as those developed by the ALCSE-INCLUDES partnership will be available to all communities in the state.

Offering One-on-One Mentoring Support

Underrepresented minority students including students from economically disadvantaged backgrounds benefit from mentoring (Myers et al., 2010). For example, a mentoring program in New York connecting high school students from an economically disadvantaged rural community with undergraduate STEM students in the same region found these interactions increased students' interest in STEM fields (Rivera et al., 2019). A key aspect of the mentoring program was matching high school students with college mentors who provided information about college preparation and expectations, tutoring, and writing assistance (Rivera et al., 2019). The program exposed high school students to STEM opportunities through campus visits to spark their interest in college and STEM.

The Strategic Undergraduate STEM Talent Acceleration Initiative (SUSTAIN), a three-year project funded by NSF at a large private research university offered mentoring support to economically disadvantaged STEM students as one of a multi-faceted series of interventions during their first and second years of undergraduate study (Ceyhan et al., 2019). Starting in the spring of their first collegiate year, participants were paired with experienced STEM faculty mentors to observe and participate in mentor-facilitated laboratory activities (Ceyhan et al., 2019). Seventy-three percent of participants reported that the individual mentoring helped them better understand science and scientific processes and 62% reported that it helped shape their career choices (Ceyhan et al., 2019).

Another example of successful mentoring is the NSF's Computer Science, Engineering, and Mathematics Scholarships (CSEMS) program at LSU. CSEMS aimed to provide greater access and support to academically talented students from economically disadvantaged backgrounds and unlike other models, the LSU program supported and provided resources for developing effective faculty-student relationships and encouraged students to secure research mentors based on their individual research interests (Wilson et al., 2012). To develop their mentoring relationship-building skills, faculty mentors attended a training session sponsored by the Office of Strategic Initiatives (OSI), wrote a letter of introduction to students, and met frequently with students. The study shows that targeted mentoring contributed to improving the graduation rates of participants.



Providing Adequate Technology and Technology Support

In working to close the digital divide during the COVID-19 pandemic, joint efforts by non-profit organizations and telecommunication companies donated computers and connected economically disadvantaged families with affordable internet access (Pace et al., 2020). These efforts were made to ensure that students from economically disadvantaged households could participate in online learning and support their transition to virtual learning (Pace et al., 2020). Such temporary measures overlook the systemic nature of the digital divide and how an inequitable funding system limits accessibility of STEM to students from economically disadvantaged backgrounds. Ramsay-Jordan (2020) explored policies and practices from socioeconomic and racial perspectives to understand the disparity in STEM experiences, specifically for Black children. The study found that inequitable funding systems perpetuates the existing inequity in access to STEM fields. The study also implies that there is a strong connection between funding system and resources including availability of adequate technology and the academic performance of students from economically disadvantaged backgrounds. To address this challenge, the study noted the need for deliberate and intentional strategy for equity.

The NSF-funded S-STEM "Tech Star" project is an example of a program that bridges technological gaps for students. The program started in 2004 to address prospective scholars' limited access to a personal computer with the software and capability to do assigned work when off-campus. Through this program, students received a loan-to-own laptop computer with appropriate software, scholarship awards along with books, tuition, and supplies, and a free mobile wireless internet device. "The combination of the scholarship with technology support and adherence to the curriculum layout has made on-time graduation and success possible for students who otherwise would not have been able to complete associate degrees in engineering technology or related advanced technologies covered by the S-STEM scholarship program" (Craft, 2016, p. 2).

Offering Out-of-School STEM Programming

Students from economically disadvantaged backgrounds face barriers such as transportation that can result in their absence from extracurricular and out-of-school activities. The role of informal STEM education environment for underserved and underrepresented students has long been documented (Hodges et al., 2017; Ihrig et al., 2018). Rural schools face a unique challenge of preparing students for STEM postsecondary education, and research on the outcome of informal STEM for underserved rural population is sparse. Apart from geographical isolation from informal science spaces, rural students also have limited bandwidth to support advanced course work in STEM that requires online access and full adoption of technological advances (Ihrig et al., 2018).

Another study looked into the impact of enriched and high-quality out-of-school programs on students from economically disadvantaged backgrounds and found these programs have the potential to mitigate some of the historical trends in academic performance (Hodges et al., 2017). The study was based on a project in the Midwest that provided enrichment class in a Saturday program to 137 economically disadvantaged and high potential students. The program lasted for six consecutive weeks and one summer program lasting five consecutive days. The study showed that attending the summer program had a positive effect on students' scores on the state's standardized assessment in both mathematics and English/language arts. Notwithstanding the result of the study, relying on test-scores alone perpetuate the existing bias of standardized testing against students from economically disadvantaged background.

The STEM Excellence program, designed to prepare rural, high-achieving middle school (Grades 6–8) students for advanced STEM educational pathways found exposure to the program increased student's awareness of mathematics and science activities (Ihrig et al., 2018).

Focusing on Targeted Recruitment Strategies

Recruitment is one of the key components of university programs seeking to diversify their student population. Within STEM fields, graduate programs are in steep competition to attract students who may represent the future of the discipline. Based on an interview with STEM graduate program leaders and a survey of STEM graduate program staff from 17 U.S. universities, Wall Bortz et al. (2020) demonstrated the lack of alignment between common recruitment strategies and faculty values and students' preferred processes for choosing a graduate program. The survey evidence and interviews with program leaders suggest programs would benefit from taking into account students' individual needs and decision-making factors rather than relying on the common practice of increasing financial incentives. They suggest programs reallocate funds to improve other aspects of the program, such as expanding resources for research endeavors or supporting students' long-term research program. The authors indicated that using evidence-based and supportive graduate recruitment strategies has a greater success at recruiting a diverse student body in the long-term.

Shadding et al. (2016) explored the cost of recruitment strategies using a summer program, Opportunities in Genomics Research (OGR), targeted at underrepresented minority students, including socioeconomically disadvantaged students. The research found lower-cost mechanisms such as emails and well-designed websites were as effective as higher-cost mechanisms (e.g., events and personal check-ins) in recruiting students who persisted to doctoral programs. Moreover, using interviews and observations from 10 highly selective doctoral programs, Posselt (2014) determined that in the two-tiered admission review process, diversity is often relegated to a secondary consideration, with test scores as a conventional primary criterion. This review process filters out many students of color, including economically disadvantaged students, whose diversity contribution might be an asset to the program. To address this oversight, Posselt recommended more efficient approaches to holistic review and strengthening incentives to recruit a diverse student body.

Key Takeaways

The strategies featured in this brief are program-level interventions. Research suggests that academic institutions could improve access and participation for students from economically disadvantaged backgrounds by investing in financial support infrastructure, mentoring programs, hands-on learning, out-of-school programming, technology support, and targeted recruitment outreach. Each of these strategies on their own is insufficient for meeting economically disadvantaged students' needs, rather a holistic approach combining multiple strategies is likely to help students succeed.

Additionally, for broader impacts, it's critical to disrupt the inequities woven into the systemic structures and policies that exist within and beyond academic institutions (Estrada et al., 2016). More specifically, it is essential that academic institutions implement institutional-level policies and practices that engage students from economically disadvantaged backgrounds in STEM-related fields and support their progression in STEM education and career pathways (Ceyhan et al., 2020). Increasing socioeconomic resources for students from economically disadvantaged backgrounds may promote equity in educational achievement.

Regarding virtual learning, it is clear that the digital divide has further deepened in the era of COVID-19 with students from economically disadvantaged communities experiencing major obstacles in accessing online education. In addition to the typical struggles to succeed in school, students are falling behind at alarming rates in achieving their academic goals, facing isolation, and losing motivation (National Student Clearinghouse Research Center, 2020). The COVID-19 pandemic has forced many educational institutions to re-think their traditional approaches and has elevated the role of technical support for sustaining students from economically disadvantaged backgrounds.

Next Steps

To further promote this brief as well as learn about other strategies that have been found effective in increasing access and participation of students from economically disadvantaged backgrounds in STEM, we will continue with discussions at www.includesnetwork.org. Below are a few questions to guide the conversation:

» **What strategies have you found effective in increasing the access and participation of students from economically disadvantaged backgrounds in STEM?**

» **How has your project supported learning for students from economically disadvantaged backgrounds during the COVID-19 pandemic?**

» **Which institutional structures (such as policies and practices) do you think most impedes student learning, progression, engagement, and completion in both K-12 and postsecondary education?**

INCLUDES-Funded Projects Focused on Economically Disadvantaged Populations

Abstracts were searched using these specific keywords low-income, low socioeconomic status, economically disadvantaged, and socioeconomically undeserved communities, which resulted in eight active INCLUDES awards focusing on this topic (data as of June 23, 2021).

Table 1. INCLUDES-Funded Projects Focused on Economically Disadvantaged Populations

Award #	Title	Leadership Team
2040841	NSF INCLUDES Planning Grant: Women in a Network of Discovery (WIND)	PI: Constance Wolfe Co-PIs: Sirena Hargrove-Leak, Leah Bug
2040783	NSF INCLUDES Planning Grant: Broadening Participation of Underserved Students in STEM and CTE in the Middle Grades	PI: Benjamin Williams Co-PIs: Tamara Goetz, William Sprankles, Pradeep Kotamraju, Angel Malone
2013234	NSF INCLUDES Planning Grant: Idaho STEM Ecosystem	PI: Kaitlin Maguire Co-PIs: Sarah Penney, Donna Llewellyn, Dee Mooney
2012941	NSF INCLUDES Planning Grant: Building Cybersecurity Inclusive Pathways towards Higher Education and Research (CIPHER)	PI: Hongyi Wu Co-PIs: Chunsheng Xin, Danella Zhao, Karen Sanzo, Brian Payne
2012896	NSF INCLUDES Planning Grant: Creating the Networks That Can Build and Sustain Inclusive, Workforce-Relevant STEM Courses for Underrepresented Students	PI: Julie Kochanek Co-PIs: Talia Milgrom-Elcott
1744491	NSF INCLUDES DDLP: Advanced Manufacturing Partnerships (AMP): Broadening Participation in New Hampshire's Workforce	PI: Palligarnai Vasudevan Co-PIs: Brad Kinsey, Stephen Hale, Melissa Aikens, Leslie Barber
1744467	NSF INCLUDES DDLP: The Alabama Alliance for an Inclusive Middle Grades Computer Science Preparation through Makerspaces in the Alabama Black Belt Region	PI: Shaik Jeelani Co-PIs: Bruce Crawford, Mohammed Qazi, Jeffrey Gray, Jacqueline Brooks
1744445	NSF INCLUDES DDLP: BEST BET: Broadening Experiences in Scientific Training - Beginning Enhancement Track	PI: Fadie Coleman

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Suggested Citation

NSF INCLUDES Coordination Hub & Tuskegee University (2021). Wealth, Equity, and STEM: Increasing STEM Access and Participation of Students from Economically Disadvantaged Backgrounds (Research Brief No. 6).

Acknowledgments

This research brief was prepared by Dr. Mercy Mugo and Dr. Simone Soso (QEM Network), Dr. Alemayehu Bekele (Educational Development Center), and Daniela Saucedo (SRI International). We thank our colleague Dr. Mohammed Qazi and his team from Tuskegee University who shared lessons learned from their INCLUDES project and other insights and expertise that greatly strengthened the brief.