



 LINCOLN POLICY **FAS** FEDERATION OF AMERICAN SCIENTISTS

STEM and Computer Science Education

Reforming Federal K-12 Education R&D Activities to Strengthen American Competitiveness



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Executive Summary

Improving elementary and secondary science, technology, engineering, and mathematics (STEM) education has been a long-standing priority for national security and American competitiveness. Today, the United States faces new challenges focusing national attention on the need to improve STEM education, including computer science. Widespread school closures during the pandemic caused historic learning losses and stifled American students' academic achievement. Renewed great power conflict has reenergized national concerns about American competitiveness. New technological innovations offer exciting possibilities, but also raise questions about the current and future readiness of the American workforce, especially in disciplines such as computer science, data science, and other emerging technology fields.

Since the 1950s, the United States has sought to improve STEM education to strengthen American economic and national security. Investing in federal education research and development has been a focus of these efforts. While elementary and secondary education remain largely decentralized in the United States, the federal government has sought to promote excellence in STEM fields by funding research and supporting the development of initiatives to improve STEM education, including by training teachers.

This paper reviews current federal STEM education initiatives—specifically, federal education R&D programs aimed at improving K-12 STEM (including computer science) education. According to the White House's Committee on STEM Education, the federal government spent \$3.9 billion on STEM



education programs in 2021.¹ Altogether, the federal government is spending roughly \$2 billion on federal education R&D, statistical collection, and related activities, some of which support improving STEM and computer science education and were counted in the \$3.9 billion spent annually on STEM.²

Our analysis of federal STEM education and education R&D programs shows that there is significant federal activity aimed at improving STEM education and national competitiveness. However, consistent with past reviews of these federal initiatives, it remains unclear whether and to what extent these initiatives are advancing national goals. For example, most federal education R&D projects focused on improving STEM education have not been effectively analyzed and reported on to identify potential lessons learned and promote best practices for education stakeholders.

Some federal education R&D activities appear to be having a positive impact on student learning across the United States, including in STEM subjects, such as technology projects funded through the Department of Education's Small Business Innovation Research program or Education Innovation and Research Program. Another bright spot has been utilizing R&D investments from the National Science Foundation and the Department of Education's Education Innovation and Research grant program to specifically support computer science. However, more could be done to increase transparency about the return on investment of education R&D programs, to identify evidence-based best practices, and to focus these education R&D investments on particular STEM disciplines such as computer science and data science to see even greater outcomes.

1 Office of Science and Technology Policy, White House, *Progress Report on the Implementation of the Federal STEM Strategic Plan* (December 2021), <https://www.whitehouse.gov/wp-content/uploads/2022/01/2021-CoSTEM-Progress-Report-OSTP.pdf>.

2 This is an approximate estimate. The federal government does not categorize its education R&D budget. Our estimate includes \$808 million for the Department of Education's Institute of Education Sciences, \$284 million for the Department of Education's Education Innovation and Research program (including \$87 million for STEM and computer science), and \$1.25 billion for the National Science Foundation's STEM Education Directorate. Not all of the activities conducted by the Department of Education's Institute of Education Sciences or the National Science Foundation's STEM Education Directorate involve R&D. "FY 2023 Omnibus Bill Includes Boosts for Education Research and Statistics," American Educational Research Association, December 2022, <https://www.aera.net/Newsroom/AERA-Highlights-E-newsletter/AERA-Highlights-December-2022/FY-2023-Omnibus-Bill-Includes-Boosts-for-Education-Research-and-Statistics>.



To improve national competitiveness as well as achievement and access in STEM education fields, the Biden administration and Congress should take steps to improve coordination, increase transparency about federal education R&D investments and their outcomes, and better monitor the condition of STEM education in the United States. We recommend the following:

- The Committee on STEM education should update its five-year strategic plan to require federal agencies to improve reporting about STEM and computer science education R&D projects, strengthen coordination among agencies on STEM education projects to increase efficiency, establish metrics, and evaluate program effectiveness. The Committee should also require interagency coordination among the National Science Foundation, the Department of Education, and other agencies to leverage STEM education R&D investments.
- The Department of Education should annually report findings and lessons learned from its education R&D activities and make this information available to other agencies, Congress, and the public. The Department of Education should leverage the Institute of Education Sciences' data collection capabilities and authorities to monitor access to STEM and computer science learning opportunities for American students. The Department of Education should also expand future National Assessment of Educational Progress exams to include STEM and computer science achievement assessments. The Institute of Education Sciences should conduct a meta-analysis of each of the STEM and computer science disciplines to ensure the evidence base is well understood and enable the development of additional practice guides and tools to improve STEM and computer science using the available evidence base.
- The National Science Foundation should improve its transparency about the return on investment of funded STEM education projects and make lessons learned and tools more broadly available to education stakeholders.
- Congress should conduct oversight to better understand federal STEM education activities and federal education R&D projects.



INTRODUCTION

Forty years ago, the National Commission on Excellence in Education issued a stark warning about the nation’s K-12 education system: “If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war.”³ Published during the Cold War, *A Nation at Risk* served as a wake-up call and catalyst for the national school reform movement.

Today, the challenges facing American K-12 education are even greater than they were in 1983. The 2022 National Assessment of Educational Progress (NAEP), the so-called “Nation’s Report Card,” found that the average scores of nine-year-old students declined “5 points in reading and 7 points in mathematics compared to 2020,” which represented the largest drop in reading in more than 30 years and the first-ever decline in math.⁴ More than one in three fourth-grade students scored “below basic” in reading.⁵

National Center for Education Statistics Commissioner Peggy Carr described the disappointing results as “some of the largest declines we have observed in a single assessment cycle in 50 years.”⁶ Education Secretary Miguel Cardona called the test scores “appalling and unacceptable.”⁷

The Nation’s Report Card results confirmed the devastating effects of pandemic-related school closures that prevented many students from accessing in-person instruction for long periods in 2020 and 2021. Some researchers warned that closing schools would lead to substantial learning losses, with students of color suffering the most, exacerbating equity problems that predated the pandemic, including substantial differences in students’ out-of-

3 National Commission on Excellence in Education, Department of Education, *A Nation at Risk* (April 1983), p. 6, <https://www.reaganfoundation.org/media/130020/a-nation-at-risk-report.pdf>.

4 “NAEP Long-Term Trend Results: Reading and Mathematics,” National Assessment of Educational Progress, Department of Education (2022), <https://www.nationsreportcard.gov/highlights/ltt/2022/>.

5 “NAEP Report Card: 2022 NAEP Reading Assessment,” National Assessment of Educational Progress, Department of Education (2022), <https://www.nationsreportcard.gov/highlights/reading/2022/>.

6 Lauren Camera, “Pandemic Prompts Historic Decline in Student Achievement on Nation’s Report Card,” *U.S. News and World Report*, October 24, 2022, <https://www.usnews.com/news/education-news/articles/2022-10-24/pandemic-prompts-historic-decline-in-student-achievement-on-nations-report-card>.

7 Ibid.



school learning opportunities.⁸ In 2021, the Department of Education (ED)’s Office of Civil Rights reported that “students of color have been less likely to be enrolled full-time in-person instruction during the pandemic,” and that the pandemic “deepened widespread inequalities in access and opportunity facing many students of color in public schools.”⁹ The 2022 NAEP showed that lower-performing students fell further behind their higher-performing peers.

The cost of the widespread and prolonged school closures is expected to have long-term costs on a generation of American students and undermine the nation’s economy. For example, Stanford University Professor Erik Hanushek compared American students’ test scores on the 2022 and 2019 mathematics exam and predicted that the learning losses will result in an economic cost of \$28 trillion over the next 100 years, or roughly \$70,000 per student.¹⁰ A 2021 study by the Federal Reserve Bank of San Francisco projected that “learning disruptions could lower the annual economic output 1/4 percentage point on average over the next 70 years.”¹¹

Congress and the Trump and Biden administrations responded to challenges facing K-12 education during the pandemic by providing more than \$190 billion in additional aid for state education agencies and school districts.¹² Congress and the Biden administration granted an additional \$350 billion in fiscal recovery funds for state and local governments.¹³

Nevertheless, public schools across the nation continue to face considerable challenges according to recent public school staff and parent surveys. A recent ED survey found that more than half of public schools reported “feeling

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- 8 *Challenges to Safely Reopening K-12 Schools: Hearing before the Select Subcommittee on the Coronavirus Crisis*, U.S. House of Representatives, 116th Cong. (2020) (statement of Dan Lips, Visiting Fellow, Foundation for Research on Equal Opportunity), <https://docs.house.gov/meetings/VC/VC00/20200806/110964/HHRG-116-VC00-Bio-LipsD-20200806.pdf>; Emma Dorn et al., “COVID-19 and Learning Loss—Disparities Grow and Students Need Help,” McKinsey, December 8, 2020, <https://www.mckinsey.com/industries/public-and-social-sector/our-insights/covid-19-and-learning-loss-disparities-grow-and-students-need-help>.
 - 9 Office of Civil Rights, Department of Education, *Education in a Pandemic: The Disparate Impacts of COVID-19 on America’s Students* (2021), <https://www2.ed.gov/about/offices/list/ocr/docs/20210608-impacts-of-covid19.pdf>.
 - 10 Brett Roland, “Pandemic Learning Loss Could Cost Students \$70,000 in Lifetime Earnings,” *The Center Square*, January 3, 2023, https://www.thecentersquare.com/national/article_2c856a32-8b78-11ed-b914-6b616b35e202.html.
 - 11 John Fernald, Huiyu Li, and Mitchell Ochse, “Future Output Loss from COVID-Induced School Closures,” Federal Reserve Bank of San Francisco (February 16, 2021), <https://www.frbsf.org/economic-research/wp-content/uploads/sites/4/wp2021-09.pdf>.
 - 12 “Education Stabilization Fund,” Department of Education, accessed February 27, 2023, <https://covid-relief-data.ed.gov/>.
 - 13 “Coronavirus State and Local Fiscal Recovery Funds,” Department of the Treasury, accessed February 27, 2023, <https://home.treasury.gov/policy-issues/coronavirus/assistance-for-state-local-and-tribal-governments/state-and-local-fiscal-recovery-funds>.



understaffed” at the start of the 2022–23 school year.¹⁴ Another ED survey found that 70 percent of public schools reported increases in students seeking mental health services.¹⁵ A March 2022 survey found that more than half of parents and school staff had moderate or extreme concerns about whether public schools were meeting children’s academic, social, emotional, and mental health needs.¹⁶

This historically challenging moment in American education is occurring at a time when the United States is facing new geopolitical challenges, including the return of great power competition,¹⁷ and renewed concerns about whether the American workforce is prepared for ongoing technological innovation. For example, in 2021, the National Intelligence Council’s *Global Trends 2040* report assessed that technological innovation would accelerate over the next 20 years: “The next decades will see increasing global competition for the core elements of technological supremacy, such as talent, knowledge, and markets, potentially resulting in new technological leaders or hegemonies.”¹⁸ The National Security Commission on Artificial Intelligence similarly warned, “[T]he United States risks losing the global competition for scarce AI expertise,” calling for a National Defense Education Act II.¹⁹

THE ROLE OF EDUCATION R&D AND STEM EDUCATION PROGRAMS

The latter report pointed back to a landmark federal education law that Congress passed and President Eisenhower signed into law in 1958. Enacted less than a year after the Sputnik satellite launch, the National Defense Education Act established new federal education programs and funding aiming to improve foreign language instruction and encourage research and experimentation in the use of new media to improve education.²⁰ In January of that year, President Eisenhower delivered a message to Congress on education

14 “School Pulse Panel,” Institute of Education Sciences, Department of Education, accessed February 27, 2023, <https://ies.ed.gov/schoolsurvey/spp/>.

15 Institute of Education Sciences, Department of Education, *Mental Health and Well-Being of Students and Staff During the Pandemic* (2022), https://ies.ed.gov/schoolsurvey/spp/SPP_April_Infographic_Mental_Health_and_Well_Being.pdf.

16 Institute of Education Sciences, Department of Education, *Parent, Staff, and Student Concerns About Learning During the Pandemic* (2022), https://ies.ed.gov/schoolsurvey/spp/2022_SPP_STP_Concerns.pdf.

17 Office of Director of National Intelligence, *Annual Threat Assessment of the U.S. Intelligence Community* (February 2022), <https://www.odni.gov/files/ODNI/documents/assessments/ATA-2022-Unclassified-Report.pdf>.

18 National Intelligence Council, *Global Trends 2040: A More Contested World* (March 2021), p. 64, https://www.dni.gov/files/ODNI/documents/assessments/GlobalTrends_2040.pdf.

19 National Security Commission on Artificial Intelligence, *Final Report* (March 1, 2021), p. 11, <https://www.nscai.gov/wp-content/uploads/2021/03/Full-Report-Digital-1.pdf>.

20 Pub. L. No. 86–864–872 Stat. 1580 (1968).



that argued for a stronger federal role in education. “Because of the national security interest in the quality and scope of our educational system in the years immediately ahead, however, the Federal government must also undertake to play an emergency role,” Eisenhower wrote.²¹ He called for a dramatic increase in funding for the National Science Foundation (NSF), including to train math and science teachers and to improve course content, as well as other education initiatives that would provide funding to states and local school systems to support testing and improve math and science learning. By 1959, NSF’s education programs had received a 300 percent increase in appropriations.²²

More than sixty years later, the federal government has established education R&D programs across several departments, spending roughly \$2 billion on various education R&D and statistical collection activities through ED and NSF. Studying the history of federal education R&D programs reveals some progress, but also many missed opportunities and challenges in achieving this mission to promote STEM education excellence and improve student learning opportunities across the United States.²³

In the current century, national policymakers have continued to focus federal activity on promoting STEM education. In 2007 and 2010, Congress passed the American COMPETES Acts, which were focused on promoting American competitiveness, including by strengthening STEM education.²⁴ One of the provisions of the 2010 law was to create a Committee on STEM Education (CoSTEM) within the White House to coordinate federal STEM education activities. The Committee’s 2018 national strategy report outlined the broad goals of American STEM education:

The pace of global innovation is accelerating along with the competition for scientific and technical talent. Today, the economic prosperity and national security of the United States rests increasingly on its capacity for continued scientific and technological innovation. America’s national innovation base depends more than ever on a strong, cross-sector collaboration around common

21 President Dwight D. Eisenhower, Special Message to the Congress on Education, January 27, 1958, The American Presidency Project, <https://www.presidency.ucsb.edu/documents/special-message-the-congress-education-2>.

22 National Science Foundation, *The Year of Earth Satellites: The Status of Science and Education in the United States* (1958), https://www.nsf.gov/pubs/1958/annualreports/ar_1958_sec2.pdf.

23 Dan Lips, “The Case for Reforming and Strengthening Federal Education R&D,” Lincoln Network (March 23, 2022), <https://lincolnpolicy.org/2022/the-case-for-reforming-and-strengthening-federal-education-rd/>.

24 See Congressional Research Service, R43880, *The America COMPETES Act: An Overview* (2015), <https://www.every-crsreport.com/reports/R43880.html>.



STEM education interests and goals—a STEM ecosystem—that can provide all Americans with access to high-quality STEM education throughout their lifetimes. Establishing a path to basic STEM literacy for everyone is vital to preparing a diverse workforce needed for the United States to lead and prosper in an increasingly competitive world driven by advanced technology.²⁵

In 2023, ensuring that American students are competitive in key subjects, including STEM, computer science, and emerging technology fields remains a national priority. For example, in December, the Biden administration released a new plan focusing on advancing equity and excellence in STEM education, focusing on “breaking down institutional barriers which have long stood in the way of equitable participation in the fields of science, technology, engineering, mathematics, and medicine (STEMM), and prevented the American innovation ecosystem from achieving its full potential.”²⁶

As the United States faces new geopolitical challenges, a global race for STEM talent, and an unprecedented education crisis following the pandemic, the nation once again is rethinking ways to improve student learning in key fields. A review of the current state of STEM and computer science in education reveals significant challenges. Congress and the Biden administration have an opportunity to leverage federal funding for education R&D to expand access to STEM and computer science instruction. Doing so would improve learning opportunities and career training for American students while addressing the nation’s broader economic and national security challenges.

THE STEM AND COMPUTER SCIENCE EDUCATION CHALLENGE

National and international test scores show that many American students are not proficient in mathematics and related subjects, and that they are performing below many of their peers in developed nations. The United States also lags behind the People’s Republic of China in the number of STEM postsecondary degrees awarded. While national leaders warn that the United States is engaged in a global competition for talent in STEM fields, access and equity gaps remain apparent in the K-12 education STEM ecosystem, limiting equal opportunity and American competitiveness.

25 “Equity and Excellence: A Vision to Transform and Enhance the U.S. STEMM Ecosystem,” Office of Science and Technology Policy, White House, December 12, 2022, <https://www.whitehouse.gov/ostp/news-updates/2022/12/12/equity-and-excellence-a-vision-to-transform-and-enhance-the-u-s-stemm-ecosystem/>.

26 Ibid.



American Students' Achievement and Access

The 2022 NAEP found that only 26 percent of American eighth-grade students scored at or above the proficient achievement level in mathematics.²⁷ Thirty-eight percent scored “below basic.”²⁸ The 2022 NAEP long-term trend assessment revealed that American nine-year-old students' test scores had declined since 2020, presumably due in part to the pandemic and widespread school closures.

A 2019 NAEP science assessment also found that “[a]pproximately one-third of fourth- and eighth-graders and less than one-quarter of twelfth-graders score[d] at or above NAEP Proficient in 2019.”²⁹ This assessment found that only 41 percent of 12th-graders had taken courses in biology, chemistry, and physics since 8th grade.³⁰ This suggests that a majority of American high school students are not completing coursework in these core science subjects, despite an increasing percentage of students taking science courses between 1982 and 2009.³¹ The apparent lack of focus on science instruction in American schools was also evident in early grades. The 2019 NAEP found that only 24 percent of fourth-grade teachers reported spending four or more hours on science instruction per week.³²

There is limited national data on American students' participation and achievement in computer science coursework. The NAEP does not yet evaluate American students' computer science achievement, and the National Center for Education Statistics does not yet track basic statistics about the availability of computer science courses in American elementary and secondary schools.³³ According to a report published by Code.org, in 2021, half of American high

27 “NAEP: Mathematics, Grade 8 as of 2022,” The Nation's Report Card, Department of Education (2022), <https://www.nationsreportcard.gov/mathematics/nation/achievement/?grade=8>.

28 Ibid.

29 “Results from the 2019 Science Assessment at Grades 4, 8, and 12,” The Nation's Report Card, Department of Education (2019), p. 1, https://www.nationsreportcard.gov/science/supporting_files/2019_infographic_science.pdf.

30 Ibid.

31 “Digest of Education Statistics,” Institute of Education Sciences, National Center for Education Statistics, Table 225.30, accessed February 27, 2023, https://nces.ed.gov/programs/digest/d20/tables/dt20_225.30.asp?current=yes.

32 “Student Experiences: Science,” The Nation's Report Card, Department of Education (2019), <https://www.nationsreportcard.gov/science/student-experiences/?grade=4>.

33 “Digest of Education Statistics,” Institute of Education Sciences, National Center for Education Statistics, accessed March 15, 2023, https://nces.ed.gov/programs/digest/current_tables.asp.



schools offered foundational computer science courses, and only five percent of high school students were taking computer science courses.³⁴ The report found that schools serving economically disadvantaged students were less likely to offer computer sciences courses.³⁵

International Comparisons

While there are reasons to be cautious about drawing conclusions about international student assessment comparisons,³⁶ available data suggests that U.S. students are far from leading the world in STEM achievement and that there is considerable room for improvement. For example, the White House’s STEM strategy found that as of 2018, “Americans’ basic STEM skills have modestly improved over the past two decades but continue to lag behind many other countries.”³⁷

For example, the 2019 Trends in International Mathematics and Science Study (TIMSS), which is administered to students around the world, found that American eighth-grade students’ average mathematics scores were above the averages of their peers in 28 foreign education systems and behind those in 10 other countries, including the Russian Federation.³⁸ The TIMSS test found that American eighth-graders’ average scores ranked 11th among the 46 participating education systems from around the world.³⁹ The TIMSS math and science exams found that the score gap between high- and low-achieving students in the United States was wider than in most participating countries. Similarly, the 2018 Program for International Student Assessment (PISA)

34 Code.org Advocacy Coalition, Computer Science Teachers Association, and the Expanding Computing Education Pathways Alliance, *2021 State of Computer Science: Education Accelerating Action Through Advocacy* (2021), https://advocacy.code.org/2021_state_of_cs.pdf.

35 Ibid.

36 The Congressional Research Service explains why policymakers and analysts should be cautious when making comparisons between international student test scores: “For example, consideration must be given to the alignment between academic content standards and assessments, the differences in the target population (e.g., composition of sample of participants, age, ethnicity, socioeconomic status, etc.), the differences in participating education systems (e.g., countries and jurisdictions), differences in student voluntary participation, the scale of the assessment, and differences in the precision of measurement for each assessment.” Rebecca R. Skinner, Congressional Research Service, IF11021, *National and International Educational Assessments* (2018), <https://crsreports.congress.gov/product/pdf/IF/IF11021>.

37 Committee on STEM Education, National Science and Technology Council, *Charting a Course for Success: America’s Strategy for STEM Education* (December 2018), p. 2, <https://files.eric.ed.gov/fulltext/ED590474.pdf>.

38 Institute of Education Sciences, National Center for Education Statistics, *TIMSS 2019 U.S. Highlights Web Report* (2019), <https://nces.ed.gov/timss/results19/index.asp#/math/intlcompare>.

39 Ibid.



found that American 15-year-olds' average test scores were lower than children in 24 education systems of Organization for Economic Co-operation and Development (OECD) countries.⁴⁰ In science, American teenagers performed higher than their peers in 19 OECD countries and lower than teenagers in six countries.⁴¹

Postsecondary STEM and Computer Science Degrees Awarded

In American postsecondary education, an increasing number of students are earning degrees in STEM and computer science subjects. U.S. institutions awarded 774,000 STEM degrees and certificates in 2020, an increase of 45 percent from the beginning of the decade.⁴² However, 16 percent of these degrees or certificates were awarded to “nonresident aliens,”⁴³ who may return to their country of origin after graduation.⁴⁴ Foreign students earned nearly half of the STEM doctorate degrees that year.⁴⁵ The National Center for Education Statistics reported that postsecondary institutions awarded 97,000 bachelor’s degrees in “computer or information sciences” in 2020, more than double the number awarded at the beginning of the decade.⁴⁶

The Economic Benefits of STEM and Computer Science Education

Students who earn STEM and computer science degrees have promising workforce opportunities. According to NSF, “[d]ata suggests that labor market outcomes are generally favorable for workers in STEM related occupations compared to workers in non-STEM occupations.”⁴⁷ For example, NSF highlighted economic data showing that STEM graduates were less likely to be unemployed than non-STEM graduates.⁴⁸ Moreover, the median salary for STEM workers was

40 Ibid.

41 Ibid.

42 “Digest of Education Statistics,” Institute of Education Sciences, National Center for Education Statistics, Table 318.45, https://nces.ed.gov/programs/digest/d21/tables/dt21_318.45.asp?current=yes.

43 ED’s legal terminology.

44 “Digest of Education Statistics,” Institute of Education Sciences, Table 318.45.

45 Ibid.

46 “Digest of Education Statistics,” Institute of Education Sciences, National Center for Education Statistics, Table 325.35, https://nces.ed.gov/programs/digest/d21/tables/dt21_325.35.asp?current=yes.

47 Abigail Okrent and Amy Burke, “The STEM Labor Force of Today: Scientists, Engineers, and Skilled Technical Workers,” National Science Foundation, August 2021, <https://nces.nsf.gov/pubs/nsb20212/stem-labor-market-conditions-and-the-economy#stem-and-non-stem-unemployment-in-the-time-of-covid-19>.

48 Ibid.



\$55,000 in 2019 compared to \$33,000 among non-STEM workers.⁴⁹ Graduates with computer science degrees on average earn roughly \$25,000 more than the average degree holder.⁵⁰

The economic advantages of STEM degrees should remain, as STEM talent will be increasingly in demand in the American labor market. A recent analysis by the Department of Labor found that there were currently 10 million workers in STEM positions, a number that is expected to grow by 11 percent by 2031—“over two times faster than the total for all occupations.”⁵¹ The Bureau of Labor Statistics highlighted the following careers with expected job growth over the next decade: data scientists (36 percent), information security analysts (35 percent), statisticians (33 percent), web developers (30 percent), computer and information research scientists (21 percent).⁵² NSF’s strategic plan for 2022–2026 estimated that “[o]ver the next few years, the number of Science and Engineering jobs in the U.S. is projected to grow about 40% faster than the non-STEM U.S. workforce.”⁵³ Cybersecurity in particular has many open positions for qualified workers. According to one estimate, there were more than 750,000 open cybersecurity positions in February 2023.⁵⁴

The Global STEM Talent Competition

As mentioned above, the Intelligence Community has assessed that the geopolitical competition for technology will include a competition over talent.⁵⁵ National policymakers are increasingly focused on the great power competition with China and the competition for technological superiority, including in emerging technology fields. White House National Security Advisor Jake Sullivan referenced this competition in a September 2022 speech: “China is

49 Ibid.

50 Doug Wintemute, “Highest Paying [sic] Jobs with a Computer Science Degree,” ZDNet, May 24, 2022, <https://www.zdnet.com/education/computers-tech/top-paying-computer-science-jobs/>.

51 Emily Krutsch and Victoria Roderick, “STEM Day: Explore Growing Careers,” Department of Labor blog, November 4, 2022, <https://blog.dol.gov/2022/11/04/stem-day-explore-growing-careers#:~:text=In%202021%2C%20there%20were%20nearly,the%20total%20for%20all%20occupations>.

52 Ibid.

53 U.S. National Science Foundation, *2022–2026 Strategic Plan* (2022), p. 18, <https://www.nsf.gov/pubs/2022/nsf22068/nsf22068.pdf>.

54 “Cybersecurity Supply/Demand Heat Map,” CyberSeek, accessed February 27, 2023, <https://www.cyberseek.org/heatmap.html>.

55 Office of Director of National Intelligence, *Annual Threat Assessment of the U.S. Intelligence Community*.



doubling down on its STEM talent production, but attracting and retaining the world's best STEM talent is an advantage that's ours to lose."⁵⁶

China is outpacing the United States in key areas of this talent competition. A 2021 Center for Security and Emerging Technology report projected that Chinese universities will produce 77,000 STEM doctorates annually compared to 40,000 in the United States by 2025, and that gap becomes a three-to-one advantage when Chinese students studying in the United States are excluded.⁵⁷ These gaps are apparent at earlier levels of the postsecondary system: in 2019, China awarded 1.9 million bachelor's degrees and more than 300,000 master's degrees in STEM fields, compared to 445,000 and 171,000 in the United States.⁵⁸ The 2018 White House STEM Strategy found that India and China were outpacing the United States in science and engineering bachelor's degrees awarded. Over a 15-year period, India conferred 25 percent of bachelor's degrees and China conferred 22 percent, while the United States conferred just 10 percent of the global total.⁵⁹

Equity and Access Gaps

One of the nation's competitive advantages is the diversity of our society. Yet when it comes to K-12 STEM education, the United States does not ensure that all of its students receive a high-quality education or even coursework in STEM and computer science subjects. The National Science Board in its *Vision 2030* report states, "Faster progress in increasing diversity is needed to reduce a significant talent gap," which the Board calls the "Missing Millions."⁶⁰ The National Science Board estimates that for the science and engineering workforce to be representative of the U.S. population in FY 2030, the number of women in STEM must nearly double from the number in the 2020 U.S. S&E workforce, the number of Black or African Americans must more than double, and the number of Hispanic or Latinos must triple.⁶¹

56 Jake Sullivan, "Remarks by National Security Advisor Jake Sullivan at the Special Competitive Studies Project Global Emerging Technologies Summit" (speech, Washington, D.C., September 16, 2022), <https://www.whitehouse.gov/briefing-room/speeches-remarks/2022/09/16/remarks-by-national-security-advisor-jake-sullivan-at-the-special-competitive-studies-project-global-emerging-technologies-summit>.

57 Remco Zwetsloot et al., "China Is Fast Outpacing U.S. STEM PhD Growth," Center for Security and Emerging Technology (August 2021), <https://cset.georgetown.edu/publication/china-is-fast-outpacing-u-s-stem-phd-growth/>.

58 Remco Zwetsloot, "Winning the Tech Talent Competition," Center for Strategic and International Studies (October 28, 2021), <https://www.csis.org/analysis/winning-tech-talent-competition>.

59 Office of Science and Technology Policy, *Equity and Excellence*.

60 National Science Board, *Vision 2030* (May 2020), <https://www.nsf.gov/nsb/publications/2020/nsb202015.pdf>.

61 Office of Science and Technology Policy, *Equity and Excellence*.



The economic benefits of STEM degrees and disciplines are obvious, but students growing up in poverty and children of color have less access to STEM learning opportunities. This includes the courses that are prerequisites to STEM majors and certificates; there is a similar lack of access to out-of-school STEM learning and enrichment programs.⁶² For example, while 50 percent of high schools in the United States offer calculus, only 38 percent of high schools with high Black and Latino student enrollment offer calculus.⁶³ Similar discrepancies are apparent in other subjects including advanced math, chemistry, and physics. These kinds of access gaps start early and persist throughout a student’s K-16 experience. States and local communities are not delivering high-quality science education in equal measure to all—students of color and students experiencing poverty are particularly unlikely to have high-quality science education throughout K-16.

CURRENT FEDERAL STEM EDUCATION AND R&D PROGRAMS AND FUNDING

Improving STEM education and education R&D have been long-standing priorities for federal policymakers. The following sections provide an overview of federal STEM education programs, federal education R&D programs, and the overlap in these federal initiatives.

Background on Federal STEM Programs and Funding

In 2018, the Government Accountability Office (GAO) reported that the federal government spent \$2.9 billion on 163 STEM education programs as of 2016.⁶⁴ GAO found that NSF managed 20 programs that received \$1.2 billion in funding, while the Department of Health and Human Services received nearly \$700 million for 54 programs as of 2016.⁶⁵ That year, the Congressional Research Service (CRS) wrote that the federal government supported “between 105 and 254 STEM education programs and activities at 13 to 15 federal agencies,” with annual federal appropriations “in the range of \$2.8 billion to \$3.4 billion.”⁶⁶ CRS explained that more than half of this funding went to postsecondary schools and students, including for financial aid.⁶⁷

62 Change the Equation, “The Double Disadvantage: Ensuring STEM Opportunities in Our Poorest Schools” (2017), https://www.ecs.org/wp-content/uploads/CTE_STEM-Desert-Brief_FINAL.pdf; Office of Civil Rights, Department of Education, 2015–2016 Civil Rights Data Collection: STEM Course Taking (2018), <https://ocrdata.ed.gov/assets/downloads/stem-course-taking.pdf>.

63 Office of Civil Rights, 2015–2016 Civil Rights Data Collection: STEM Course Taking.

64 Government Accountability Office, GAO-18-290, *Science, Technology, Engineering, and Mathematics Education: Actions Needed to Better Assess the Federal Investment* (2018), <https://www.gao.gov/assets/gao-18-290.pdf>.

65 Ibid.

66 Boris Granovskiy, Congressional Research Service, R45223, *Science, Technology, Engineering, and Mathematics (STEM) Education: An Overview* (June 12, 2018), <https://crsreports.congress.gov/product/pdf/R/R45223>.

67 Ibid.



A 2010 law required the White House to establish a Committee on STEM Education within the Office of Science and Technology Policy, which must periodically report to Congress on progress implementing its strategy and provide an inventory of federal STEM programs. Below is a snapshot of these programs from the Committee's 2021 report.⁶⁸

FY 2021 Number of STEM Education Investments by Agency

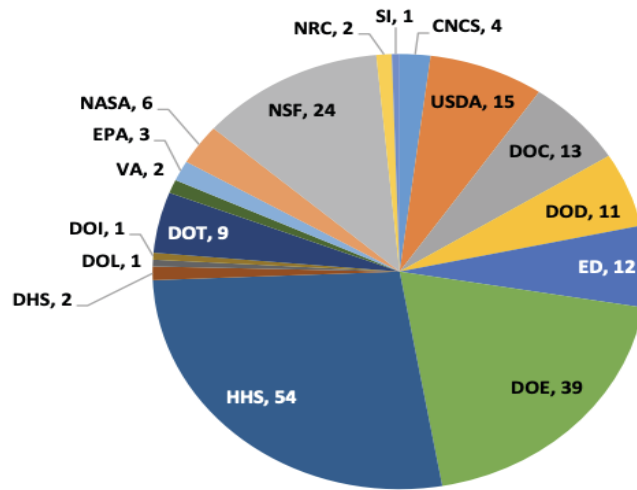
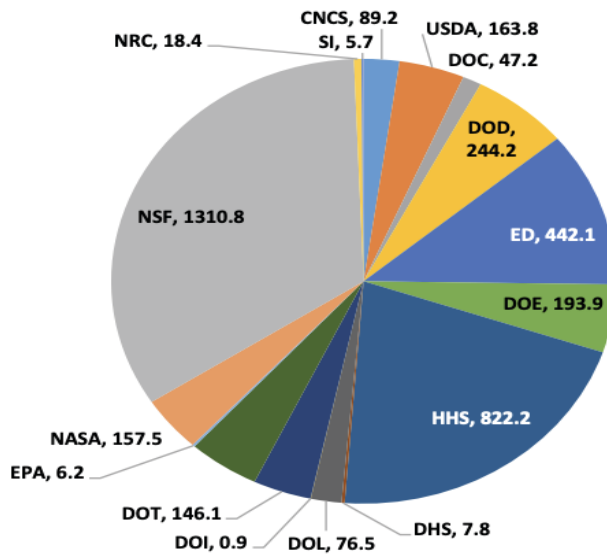
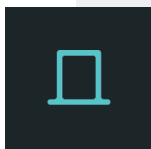


Figure 4. This pie chart depicts the information provided in the table above in the FY2021 Estimated Budget column.

FY 2021 Estimated Budget (\$, millions)



68 Office of Science and Technology Policy, White House, *Progress Report on the Implementation of the Federal STEM Education Strategic Plan* (2021), <https://www.whitehouse.gov/wp-content/uploads/2022/01/2021-CoSTEM-Progress-Report-OSTP.pdf>.



In 2022, Congress passed and President Biden signed into law the CHIPS and Science Act.⁶⁹ According to the White House, the bill “authorizes new and expanded investments in STEM education and training from K-12 to community college, undergraduate and graduate education,” and includes provisions to expand and support R&D in STEM fields.⁷⁰ A McKinsey analysis explains that the law authorizes \$174 billion in funding over five years for federal agencies to spend on STEM programs, workforce, and R&D projects, including \$80 billion authorized for NSF; however, the law did not appropriate funding for these initiatives.⁷¹ The FY2023 omnibus appropriations bill that became law in December 2022 included significant increases for STEM education programs, including a \$140 million funding increase for NSF’s STEM Education Directorate.⁷²

Current Federal Education R&D Programs and R&D Programs Focused on STEM

The federal government also provides funding for education R&D initiatives, and many of these efforts are focused on improving STEM education. While Congress has not required that the White House conduct an inventory of education R&D programs, the following is a broad overview of major department and agency initiatives.

- The **U.S. Department of Education** supports education R&D through its Institute of Education Sciences (IES), which received \$807.6 million in the FY2023 omnibus. This included \$245 million for research, development and dissemination, \$58.7 million for Regional Educational Laboratories, \$121.5 million for statistics, \$192.8 million for assessments, and other programs. IES was directed to use a portion of its FY2023 appropriation to support a new funding opportunity for quick-turnaround, high-reward scalable solutions intended to significantly improve outcomes for students. In a recent blog post, Mark Schneider, Director of IES, detailed that \$30 million of IES’s funding increase will be utilized to support more Advanced Research Projects Agency

69 Pub. L. 117-167 (2022).

70 “Fact Sheet: CHIPS and Science Act Will Lower Costs, Create Jobs, Strengthen Supply Chains, and Counter China,” White House, August 9, 2022, <https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/09/fact-sheet-chips-and-science-act-will-lower-costs-create-jobs-strengthen-supply-chains-and-counter-china/>.

71 Justin Badlam et al., “The CHIPS and Science Act: Here’s What’s in It,” McKinsey, October 4, 2022, <https://www.mckinsey.com/industries/public-and-social-sector/our-insights/the-chips-and-science-act-heres-whats-in-it>.

72 “Congress Passes FY 2023 Omnibus Spending Bill,” STEM Education Coalition, accessed February 27, 2023, <http://www.stemedcoalition.org/2022/12/26/congress-passes-fy-2023-omnibus-spending-bill/>.



(ARPA)-like methods.⁷³ ED also received \$284 million for the Education Innovation and Research (EIR) grant program, including \$87 million for STEM and computer science grants.

- **NSF’s Directorate for STEM Education’s** mission is “to develop a well-informed citizenry and a diverse and capable workforce of scientists, technicians, engineers, mathematicians and educators.” Until 2022, this Directorate was referred to as the Education and Human Resources Directorate.⁷⁴ The FY2023 funding bill provides \$1.246 billion for the STEM Directorate.⁷⁵ In addition to NSF’s STEM EDU Directorate, the CHIPS and Science Act codifies the new Technology Innovation and Partnerships Directorate (TIP) at NSF. TIP is “a new NSF directorate that creates breakthrough technologies; meets societal and economic needs; leads to new, high-wage jobs; and empowers all Americans to participate in the U.S. research and innovation enterprise.”
- The **Department of Defense Education Activity (DoDEA)** operates 160 schools that educate 60,000 students around the world for military-connected children.⁷⁶ The Department of Defense also maintains a strategic plan for STEM.⁷⁷ While not focused on education R&D, DoDEA schools have STEM initiatives and are well positioned to leverage the findings of education R&D projects to improve STEM education for the children of military personnel.

REVIEWING STEM EDUCATION R&D PROJECTS’ IMPACT

Reviewing current education R&D activities of ED reveals a broad focus on STEM education; however, there are opportunities for ED to further prioritize STEM education and to leverage the findings of past and future R&D projects to share best practices and lessons learned.

73 “Innovation in the Education Sciences (the New IES),” Institute of Education Sciences, February 2, 2023, <https://ies.ed.gov/director/remarks/02-02-2023.asp>.

74 “NSF Announces Name Changes to Education Directorate,” National Science Foundation, October 25, 2022, <https://beta.nsf.gov/news/nsf-announces-name-changes-education-directorate>.

75 “FY 2023 Omnibus Bill Includes Boosts for Education Research and Statistics,” American Educational Research Association, December 2022, <https://www.aera.net/Newsroom/AERA-Highlights-E-newsletter/AERA-Highlights-December-2022/FY-2023-Omnibus-Bill-Includes-Boosts-for-Education-Research-and-Statistics/mid/51988/>.

76 “Education Activity,” Department of Defense, accessed February 27, 2023, <https://www.dodea.edu/index.cfm>.

77 Department of Defense, *The Department of Defense Strategic Plan FY2021–FY2025* (2021), https://dodstem-assets.dodstem.us/files/DoD_STEM_Strategic_Plan_2021.pdf.



It is hard to systematically determine whether the many existing STEM education R&D programs have been successful in improving students' learning opportunities and improving access for the "missing millions." There is an opportunity to support increased knowledge about what works, for whom, in STEM and to support partnerships between agencies that could support research-based programs and innovations to reach more students while continuing to learn from bringing programs to scale.

Education Innovation and Research Program

Our analysis of ED's Education Innovation and Research program awards shows that ED provided more than \$200 million in grants to more than 200 projects that are focused on advancing STEM education between 2017 and 2022.⁷⁸ Many of these projects are focused on addressing national STEM goals, including expanding access, advancing equity by providing instruction to underserved students, and increasing student achievement in STEM and computer science courses. The following are examples of EIR-funded projects, based on information provided on ED's website:

- In 2017, the United Way of Massachusetts Bay received \$3.9 million for the BoSTEM project to provide STEM learning experiences to more than 1,000 high-need students, with a focus on preparing them for postsecondary education.⁷⁹
- In 2018, SRI International received \$3.9 million for a mathematics, 3D printing, and computational thinking project for California middle school students by using "digital fabrication (3D modeling and printing), designed for students to learn mathematics, computational thinking, and spatial thinking skills, as well as develop positive views of themselves and their future in STEM."⁸⁰

78 This is a conservative estimate of the amount of funds provided to these EIR projects, based on our analysis of the grant awards listed on the EIR website from FY2017 to FY2022. This amount reflects only the initial grants awarded to projects and does not include potential follow-up funding that the project sponsors received. "Education Innovation and Research Awards," Office of Elementary and Secondary Education, Department of Education, updated February 24, 2023, <https://oese.ed.gov/offices/office-of-discretionary-grants-support-services/innovation-early-learning/education-innovation-and-research-eir/awards/>.

79 United Way of Massachusetts Bay, Department of Education, BoSTeM, *Narrative: United Way of Massachusetts Bay and Merrimack Valley*, accessed March 10, 2023, <https://oese.ed.gov/files/2016/12/U411C170195-United-Way-of-Massachusetts-Bay-Inc-Project-Narrative.pdf>

80 SRI International, Department of Education, *SRI Proposal No. 18-060-654-EDU*, accessed February 27, 2023, <https://oese.ed.gov/files/2019/11/U411C180070-SRI-International-Narrative.pdf>.



- In 2019, the National Math and Science Initiative received \$1 million for a project to expand access to a computer science AP exam to 50 schools across Texas by 2023.⁸¹ That year, the Alabama State Department of Education received an \$800,000 grant to expand access to computer science instruction by providing professional development to training and counselors.⁸²
- In 2020, Duval County Public Schools in Florida received \$3.5 million to use Minecraft to teach science to K-5 students with a focus on helping children with disabilities.⁸³
- In 2021, Urban Arts Partnership received nearly \$700,000 to develop a curriculum and pedagogical methodology to provide computer science instruction using a video game design to serve North Carolina students.⁸⁴
- In 2022, the College Bridge received nearly \$850,000 to serve “nearly 8,000 low-income, Black, or Hispanic 11th or 12th grade students in rural high schools that lack access to rigorous math courses.”⁸⁵

However, the ED’s Education Innovation and Research Program does not appear to provide annual or regular reporting about the programs that have been funded, their impact, and lessons learned for other stakeholders in K-12 education. Identifying best practices or other lessons revealed through these potentially innovative projects could provide insight into how schools, teachers, and organizations can improve STEM education learning and help achieve the national goals discussed above.

81 National Math and Science Initiative, Department of Education, “Lone Star Advanced Placement (AP) Computer Science Principles (CSP),” accessed February 27, 2023, <https://oese.ed.gov/files/2019/10/Abstract-for-National-Math-and-Science-Initiative.pdf>.

82 Alabama State Department of Education, Department of Education, “Abstract: Assessing the Statewide Impact of K-12 Computer Science Pathways: Increasing Teacher Preparation and Expanding Student Computational Literacy,” accessed February 27, 2023, <https://oese.ed.gov/files/2019/10/Abstract-for-Alabama-State-Department-of-Education.pdf>.

83 Duval County Public Schools, Department of Education, “Abstract: Ultra—Minecraft Mentor Edition,” accessed February 27, 2023, <https://oese.ed.gov/files/2020/12/S411C200018-DUVAL-COUNTY-PUBLIC-SCHOOLS-Abstract.pdf>.

84 Urban Arts Partnership, Department of Education, “Abstract: Game On: Teaching The AP CSP Through Game Design,” accessed February 27, 2023, <https://oese.ed.gov/files/2021/12/S411C210110-Abstract.pdf>.

85 College Bridge, Department of Education, “Executive Summary: The Dual Enrollment Math Bridge (DE Math Bridge) Project: An Innovating High School Intervention to Close Equity and Attainment Gaps in College Math and College Completion,” accessed February 27, 2023, <https://oese.ed.gov/files/2022/12/S411C220047-The-College-Bridge-Inc-Abstract.pdf>.



Regional Educational Laboratories and Research and Development Centers

For more than a half century, ED, and its precursor office, have funded the Regional Educational Laboratories (REL) program to provide research support and assistance to school districts and other education stakeholders.⁸⁶ ED also funds Research and Development Centers, through its National Center for Education Research.⁸⁷ In FY2022, the REL program received \$57 million,⁸⁸ and the Research and Development Centers program received \$9 million.⁸⁹

In 2023, the funding for REL and R&D Centers are not targeted to improve STEM and computer science education. For example, STEM education research does not appear to be a focus of the RELs research activity, based on the “topics” listed on ED’s REL website, and individual disciplines science, engineering, and computer science are also missing. Topics include mathematics, college and career readiness, and equity, but science, technology, engineering, and computer science are not mentioned. The R&D Centers are statutorily required to focus on specific topics listed in the federal Education Sciences Reform Act; however, these topics do not include STEM or computer science education.⁹⁰ In its budget proposal for FY2023, the Biden administration requested that Congress update the law to provide greater flexibility for how ED uses its funding and to eliminate the list of research topics.⁹¹ “The existing list, created in 2002 is outdated,” the Biden administration wrote, “and IES as a science agency needs flexibility to identify and implement research strategies based on current and emergent needs and challenges in the field of education.”⁹²

86 “The Regional Educational Laboratories (REL) Program,” Institute of Educational Sciences, Department of Education, accessed February 27, 2023, <https://ies.ed.gov/ncee/rel/>.

87 “Research and Development Centers,” National Center for Education Research, Institute of Education Sciences, Department of Education, accessed February 27, 2023 <https://ies.ed.gov/ncer/research/randdCenters.asp>.

88 Department of Education, *Fiscal Year 2023 Budget Summary* (2022), <https://www2.ed.gov/about/overview/budget/budget23/summary/23summary.pdf>.

89 Department of Education, *Institute of Education Sciences: Fiscal Year 2023 Budget Request* (2022), <https://www2.ed.gov/about/overview/budget/budget23/justifications/v-ies.pdf>.

90 Jeffrey J. Kuenzi and Adam Stoll, Congressional Research Service, R43398, *The Education Sciences Reform Act* (2014), <https://sgp.fas.org/crs/misc/R43398.pdf>.

91 Department of Education, *Institute of Education Sciences: Fiscal Year 2023 Budget Request* (2022), <https://www2.ed.gov/about/overview/budget/budget23/justifications/v-ies.pdf>.

92 *Ibid.*, p. 11–12.



Small Business Innovation Research Program

ED also supports R&D through its Small Business Innovation Research (SBIR) program, which is authorized by the Small Business Innovation Development Act of 1982, a law that was reauthorized in 2020.⁹³ Through SBIR, ED awards contracts to small businesses to develop education technology projects and to support research to evaluate their effectiveness, with annual funding of approximately \$10 million.⁹⁴ The SBIR program provides detailed summaries of successful technology development projects that were funded, research conducted, and lessons learned. For example, the SBIR website provides 25 examples of successful technology products that were funded, describing each as having “been disseminated or commercialized in the private marketplace,” “in use by students and teachers on a widespread basis,” and having “a viable mechanism in place to enable continued commercial success.”⁹⁵ The following are examples of SBIR’s self-described “success stories” that focus on STEM learning:

- **MidSchoolMath:** Over the past decade, ED awarded \$1 million to MidSchoolMath to support the development of EMPIRES, an online and in-person video game to teach middle school students mathematics skills through the content of managing the ancient civilization of Mesopotamia. Research evaluations found a high re-enrollment rate for participating children and evidence from a randomized experiment showing that students who used the EMPIRES game outperformed their peers in several math skills. The company has commercialized the service, which has served 40,000 students.⁹⁶
- **Future Engineers:** Since 2016, ED has awarded nearly \$1 million to Future Engineers, “an online, multi-challenge platform for administering educational contests and challenges in or outside of K-12 classrooms.”⁹⁷ To date, the platform has been used by more than 50,000 students and has hosted a NASA contest.⁹⁸

93 “ED/IES Small Business Innovation Research: Program & Application Information,” Institute of Education Sciences, Department of Education, accessed March 15, 2023, <https://ies.ed.gov/sbir/applicant.asp>.

94 Department of Education, *Institute of Education Sciences: Fiscal Year 2023 Budget Request*.

95 “IES/SBIR Success Stories,” Institute of Education Sciences, Department of Education, accessed February 27, 2023, https://ies.ed.gov/sbir/success_stories.asp.

96 “Success Stories out of the Institute of Education Sciences’ SBIR Program: MidSchoolMath’s EMPIRES,” Institute of Education Sciences, Department of Education, accessed February 27, 2023, <https://ies.ed.gov/sbir/MidSchoolMath.asp>.

97 “Success Stories out of the Institute of Education Sciences’ SBIR Program: Future Engineers,” Institute of Education Sciences, Department of Education, accessed February 27, 2023, https://ies.ed.gov/sbir/future_engineers.asp.

98 Ibid.



- **HoloLAB Champions:** Since 2016, a \$1-million grant has supported the development of a virtual reality chemistry lab game to teach students lab skills, including safety. According to the company, research conducted by its partner RAND Corporation found that the program worked effectively.⁹⁹ While the game requires virtual reality equipment, the company made the service available for free for teachers and students during the pandemic.¹⁰⁰
- **Teachley:** \$1 million in grant funding supported the development of math game applications called Teachley Operations, which were based in part on prior research, supported by an ED grant, that was conducted by Columbia University’s Teacher College. The games teach students mathematics skills, including efficient addition, subtraction, and mathematics strategies, while providing data to teachers who can provide personalized mathematics instruction. The subscription-service app has been downloaded more than 1 million times, and more than 2,000 schools are using the service.¹⁰¹

ED’s SBIR program provides transparency about other investments, including by publishing a searchable table of all funded projects since 2002. ED could provide greater insight into the impact on student outcomes and return on investment of all of the SBIR grants awarded; however, simply publishing examples of success stories provides a rare example of federal education R&D programs showing how funded projects have been scaled, including through commercialization.

NSF Programs

As mentioned above, NSF has several initiatives focused on or involving activities aimed to strengthen STEM education, including through R&D. The new STEM Education Directorate, formerly known as the Education and Human Resources Directorate, receives more than \$1 billion in funding according to the FY2023 NSF budget submission.¹⁰² NSF’s website provides examples of successful STEM education projects that were funded by federal grants:

99 Institute of Education Sciences, Department of Education, Institute of Education Sciences, “Success Story Out of the ED/IES SBIR Program: Schell Games” HoloLAB Champions,” accessed February 27, 2023, <https://ies.ed.gov/sbir/Holo-lolab.asp>.

100 Ibid.

101 “Teachley: Math Facts—Design And Development Of Intervention Software Promoting Single-Digit Operational Fluency,” Institute of Education Sciences, Department of Education, accessed February 27, 2023, <https://ies.ed.gov/sbir/teachley.asp>.

102 U.S. National Science Foundation, FY 2023 Budget Request to Congress: Directorate for STEM Education Funding by Division and Program (2022), https://www.nsf.gov/about/budget/fy2023/pdf/08_fy2023.pdf.



- **Muzology**, an SBIR-funded project to use technology and music to “support the learning of critical academic skills and concepts,”¹⁰³ including math videos for students in grades 5–9.¹⁰⁴
- **Engineering is Elementary**, a program managed by the Museum of Science in Boston for “developing lessons to engage students in grades 1–5 in engineering activities integrated with their science lessons.”¹⁰⁵ NSF provided nearly \$3 million in grants from 2005 to 2008 to support the program. The program has benefited students, according to NSF-funded research evaluations.¹⁰⁶ The program now offers computer science and engineering courses to elementary and middle schools for purchase on its website,¹⁰⁷ as well as professional development and free STEM activities for children and families to use.¹⁰⁸

While the NSF website includes a database of past grant awards and current grant funding available, the foundation could provide more insight to Congress and the public by providing an annual review of past and future STEM research projects funded, identifying lessons learned and best practices or tools that education stakeholders may use.

Computer Science Principles: A Bright Spot in Deploying Education R&D Resources to Improve Outcomes for Underserved Students

As states started to adopt computer science standards and prioritize computer science in their planning, NSF and ED sought to amplify these efforts and determine ways to support increased access and participation in computer science. In particular, NSF and ED took complimentary steps to support computer science education and particularly to spur the creation of new learning experiences in computer science focused on broadening participation.

103 America’s Seed Fund, National Science Foundation, “Muzology LLC,” accessed February 27, 2023, <https://seedfund.nsf.gov/awardees/history/details/?company=muzology-llc>.

104 Muzology homepage, accessed February 27, 2023, <https://www.muzology.com/>.

105 “Engineering is Elementary,” National Science Foundation, SBIR, https://nsf.gov/awardsearch/showAward?AWD_ID=0454526.

106 “Research,” Engineering is Elementary, accessed February 27, 2023, <https://www.eie.org/research>.

107 Engineering is Elementary homepage, accessed February 27, 2023, <https://www.eie.org/>.

108 Ibid.



NSF invested in Exploring Computer Science along with Advanced Placement Computer Science Principles in 2015.¹⁰⁹ NSF also provided resources to pilot and study different courses that are endorsed by the College Board, including Beauty and Joy of Computing, Mobile CSP (Computer Science Principles), and Thriving in our Digital World. The launch of the new AP Computer Science Principles course has allowed more students to study computer science in high school. Research by the College Board shows that students who take AP Computer Science principles are three times more likely to major in computer science than their peers who did not take the course.¹¹⁰

ED has prioritized computer science in its EIR grant program. At least four EIR Grantees have received grants to support increased access to computer science principles across different geographies and communities. ED also issued a “Dear Colleague” letter in 2016¹¹¹ that made it clear that state education agencies, local education agencies, and their partners could use formula and discretionary grant resources to support STEM, including computer science.¹¹²

NSF spurred the development of a new framework, new courses, and teacher professional development models. And through both non-regulatory guidance and grant resources, ED has been able to support increased scale and learning about ways to support equity and access within the programs. These investments have led to increased access to computer science principles. From the AP CSP launch in 2017 to 2020, the number of CSP exam takers rose 160 percent.¹¹³

This is a bright spot in using federal funds to support STEM education, demonstrating what is possible when education R&D is deployed towards a particular and well-defined challenge in K-12 education. NSF invested in developing and research courses and teacher professional development models with the goals of broadening participation in computing. ED deployed R&D resources through EIR along with executive actions to support scaling computer science. With each agency playing a role and coordinating with other agencies,

109 “College Board and NSF Expand Partnership to Bring Computer Science Classes to High Schools Across the U.S.,” National Science Foundation, June 4, 2015, https://www.nsf.gov/news/news_summ.jsp?cntn_id=135335.

110 “AP Computer Science Principles: Research Findings,” College Board, December 2020, <https://apcentral.collegeboard.org/courses/ap-computer-science-principles/ap-csp-research-findings>.

111 This Dear Colleague letter was updated and re-released in December 2022. “Dear Colleague Letter,” Department of Education, April 13, 2016, <https://www2.ed.gov/programs/promiseneighborhoods/stemdearcolleagueaccess.pdf>.

112 “Key Policy Letters Signed by the Education Secretary or Deputy Secretary,” Department of Education, December 6, 2022, <https://www2.ed.gov/policy/gen/guid/secletter/221206.html>.

113 “AP CS Data for 2020,” CS4All blog, December 11, 2020, <https://cs4all.home.blog/2020/12/11/ap-cs-data-for-2020/>



these actions resulted in an increase in access, particularly for students who identify as girls, Black, Hispanic and first-generation college students.¹¹⁴ While there is more work to be done, this example is one that we should learn from.

RECOMMENDATIONS

As the Office of Science and Technology Policy begins work on the next five-year strategic plan for STEM education and the workforce, there are a few actions that agencies and the administration could take that would be extremely beneficial for the field. There are many programs that have received education R&D funds from the federal government to support STEM, including some successful projects. However, there are areas for improvement.

- **The Committee on STEM Education should update its five-year strategic plan and require federal agencies to improve reporting about STEM R&D projects, strengthen coordination among agencies about STEM projects to increase efficiency, and establish metrics for better tracking the nation's progress toward achieving national strategic goals.** The Committee has a mandate to guide the federal government's strategy for STEM education and improve how current R&D investments are used to improve STEM education achievement, access, and equity.¹¹⁵
- **The Committee on STEM Education should require interagency coordination among NSF, ED, and other agencies to leverage STEM education R&D investments.** Improving coordination among agencies involved in federal education R&D activities has the potential to increase the return on investment from federal expenditures and to scale promising activities to improve STEM achievement. In addition, the Department of Defense should coordinate with ED and NSF to identify opportunities for DoDEA to use best practices from education R&D activities to improve learning opportunities for the children of military personnel.

114 Jeff Wyatt, Jing Feng, and Maureen Ewing, "Computer Science Principles and the STEM and Computer Science Pipelines," College Board (December 2020), <https://research.collegeboard.org/media/pdf/AP%20Computer%20Science%20Principles.pdf>

115 National Science and Technology Council, White House, *Charter of the Committee on Science, Technology, Engineering, and Mathematics (STEM) Education* (February 1, 2011), https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/costem_charter_signed_01-31-11.pdf.



- **ED should annually report findings and lessons learned from its education R&D activities, including EIR-funded projects, and make this information available to other agencies, Congress, and the public.** ED and IES should highlight the impact on student outcomes and return on investment of these expenditures. Moreover, ED should improve the transparency of its R&D programs by regularly publishing findings of federally funded research and by publishing third-party evaluations on ED’s website. ED should also use its communications capabilities to spotlight promising STEM education models to inform stakeholders about potential models. Identifying potential best practices and models that can be replicated by other agencies, school districts, and schools should be a focus of federal education R&D initiatives to increase the return on investment from federal expenditures.
- **ED should leverage IES’s data collection capabilities and authorities to monitor access to STEM and computer science learning opportunities for American students.** For example, the National Center for Education Statistics should survey access to STEM and computer science courses and teachers in elementary and secondary schools to identify potential gaps and opportunities to improve equity and access. IES could also use the current school pulse panel to provide snapshots of STEM education access and achievement in K-12 schools. Greater transparency about the condition of STEM and computer science education in American schools could inform future federal education R&D activities and other education interventions.
- **Expand future NAEP tests to include STEM and computer science achievement assessments.** Given the long-standing national security concerns regarding U.S. students’ performance and workforce talent gaps in STEM education, Congress and ED should expand future NAEP tests to include additional assessments focused on computer science or other emerging technology fields. There is a precedent for this type of assessment, since NAEP has administered a “Technology and Engineering Literacy” test as recently as 2018.¹¹⁶ Conducting future assessments in computer science or emerging technology subjects could yield important insights about American students’ achievement levels and progress, and identify opportunities for improvement. Assessing student performance in these subjects would also incentivize schools to place more emphasis on these subjects.

116 “NAEP Report Card: Technology & Engineering Literacy (TEL): Highlights from the 2018 Assessment,” National Assessment of Educational Progress, accessed February 27, 2023, https://www.nationsreportcard.gov/tel_2018_highlights/.



- **NSF should improve its transparency about the return on investment of funded STEM education projects and make lessons learned and tools more broadly available to education stakeholders.** Improving Congress and the public's understanding of R&D projects and using any products or services that have been developed to improve American students' learning opportunities should be priorities for NSF moving forward.
- **Congress should conduct oversight to better understand federal STEM education activities and federal education R&D projects.** For example, Congress should direct GAO to update its review of federal STEM education programs to assess how these activities are advancing national goals and identify opportunities to improve program performance and efficiency. Congress should also direct GAO to review ED's R&D programs to analyze what can be learned from education research projects. In addition, congressional committees should hold hearings on these topics with a focus of identifying best practices.

CONCLUSION

The United States faces significant challenges in K-12 education. School closures during the pandemic led to widespread learning losses and expanded the academic achievement gap between disadvantaged students and their peers. The return of great power competition and ongoing technological changes have placed renewed attention on the need to ensure that American students remain competitive with students around the world. For decades, improving American competitiveness by promoting STEM education and using R&D to improve access has been a bipartisan national priority.

In 2023, the Biden administration and Congress should focus on improving the efficiency of current federal STEM and R&D programs to advance our national goals, expand access to STEM and computer science education learning opportunities, and spur ongoing improvement in American schools.



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