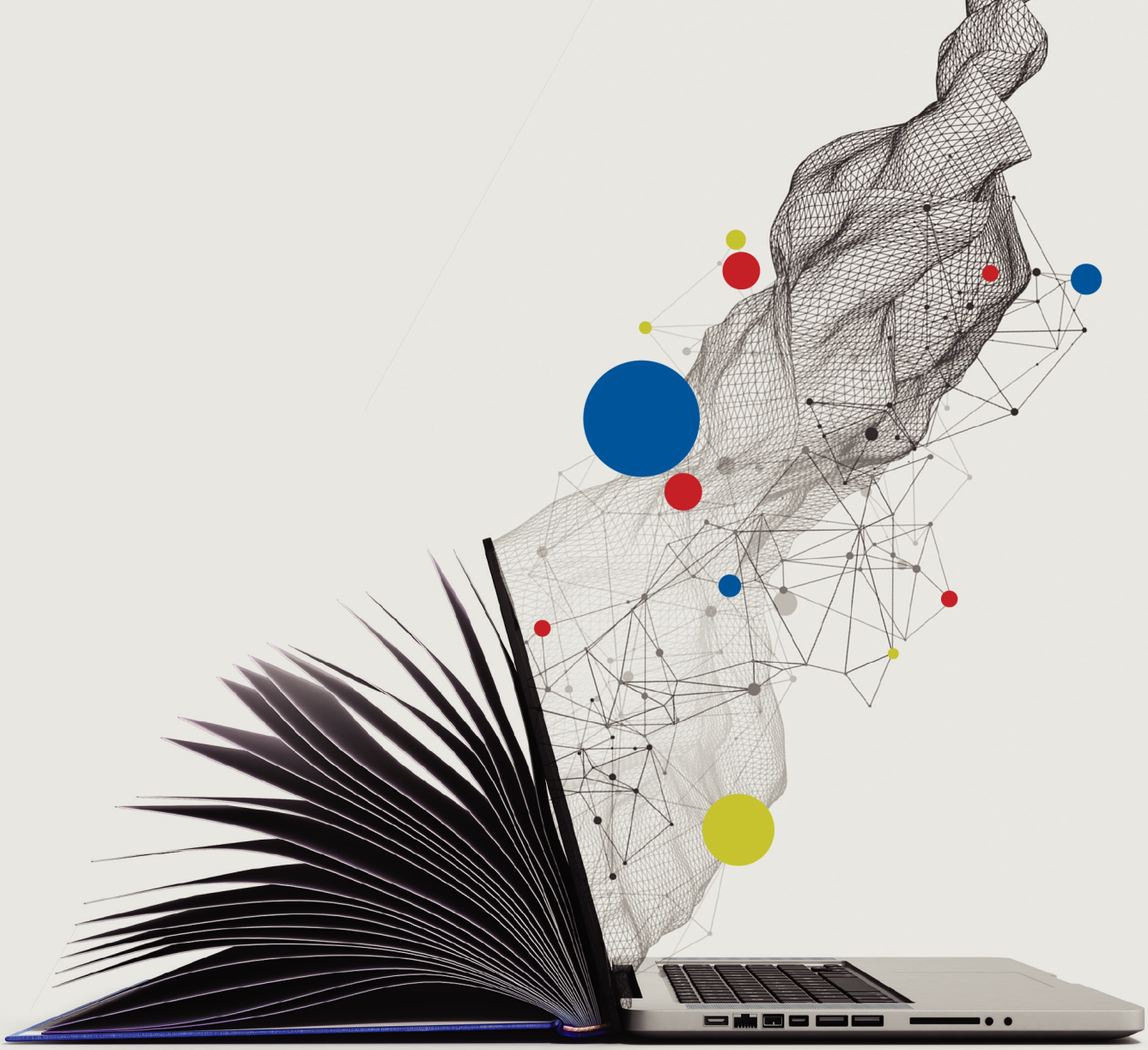

RE-ENGINEERING AMERICAN SECURITY

CULTIVATING TALENT FOR COMPETITIVENESS

Edited by Dan Correa, Chris Howard,
Emily Lawrence, and Anja Manuel

aspen strategy group
aspen institute

Aspen Strategy Group
The Aspen Institute
2300 N Street, NW | Suite 700
Washington, DC 20037
Phone: 202.736.5800

The Aspen Institute
2300 N Street, NW | Suite 700
Washington, DC 20037

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PROLOGUE

For decades, America's position in the world has relied on the principles outlined in our founding documents, underpinned by our economic strength and technological leadership. As near-peer adversaries challenge the primacy of America's innovation ecosystem, we risk losing this competitive edge. **The U.S. needs an education system capable of training the workforce of tomorrow to keep our innovation lead.**

To address this critical challenge, the Aspen Strategy Group recently convened three roundtable discussions **focused on the intersection of innovation, education, and national security.**

Since its founding in 1984, the Aspen Strategy Group has provided a resolutely nonpartisan forum for decision-makers and thought leaders to consider the key foreign policy and national security issues facing the United States. For this project, we convened a high-level group of creative thinkers from the business, education, nonprofit, and national security sectors to transcend the silos in which we often operate and find new ways to strengthen America's K-12, university, and career and technical education ecosystem to secure our technological edge.

To maintain our competitive advantage, the United States needs a two-pronged approach to its innovation strategy. We must invest both in the sectors that are most critical to our national security—including artificial intelligence, 5G/6G technologies, semiconductors, quantum computing, and more—**and, importantly, in the human talent that will support those sectors and the innovations to come. Therefore, the U.S. must create a cohesive strategy that aligns its national security with a first-rate K-12 and higher education system.**

This report summarizes the main ideas from the roundtable discussions, though it does not necessarily reflect a consensus of all the meeting participants. We hope that the policy recommendations that follow will contribute to the efforts to improve our education system and ensure a domestic pipeline of talent for the challenges and jobs of the future.

Disclaimer: This report does not necessarily reflect a consensus of all the meeting participants, the Aspen Strategy Group, or the Aspen Institute.

EXECUTIVE SUMMARY

America is engaging in the global technological competition with an education system that is not fit for purpose—it does not adequately prepare our students. We are no longer keeping pace with other countries, particularly China, in K-12 and higher STEM education outcomes.

The U.S. needs a renewed commitment to an education system capable of training the workforce of tomorrow to keep our innovation lead.

To address this, the Aspen Strategy Group convened a high-level group of creative thinkers from the business, education, nonprofit, and national security sectors to transcend the silos in which we each often operate and find new ways to strengthen America's K-12 and higher education ecosystem to secure our technological edge.

We recommend the following:

- **Leverage the National Security Community to Promote Education as a Priority**
  To make real change in our failing education system, the U.S. needs the national security community to weigh in on education as a national security priority. This working group and report is a step in that direction.

- **Utilize the National Defense Authorization Act as a Vehicle for Change**
  The National Defense Authorization Act (NDAA) passes every year and still engenders bipartisan collaboration in Congress. We can include provisions in the NDAA that support education, such as initiatives inspired by the successful 1958 National Defense Education Act. We could also create an "ROTC for teachers" by allocating some funding to cover higher education costs for teachers if they agree to teach K-12 STEM afterwards. Finally, we must use existing Department of Defense education programs that support STEM education to better effect.

- **Bolster and Deepen Our Investments in Education R&D**
  Existing methods will not be enough to revive our education system. Education R&D can lead us to groundbreaking innovations that would dramatically improve student performance, but we are severely underinvesting in it. We need to create and fund an entity like the Defense Advanced Research Projects Agency (DARPA) for education R&D that can develop new creative ways to engage students in STEM. We also need to unlock our existing data on education outcomes, so we can better understand what methods are and are not working. We must also strengthen programs supporting education innovation at the National Science Foundation and balance *research* into how learning works with the *development* and *deployment* of successful programs.

- **Align Student Learning Pathways with the Skills They Will Need**
  We must ensure that K-12 partners are included in existing plans for federal development funding so that programs supporting U.S. economic prosperity—such as in the CHIPS and Science Act and Build Back Better Act—are used to make long-term investments in our students and future workforce to sustain them. We should also make it easier for students to become productive workers through pathways other than college, by improving our apprenticeships and career and technical education opportunities.

By doing so, we will strengthen our education system, generate breakthroughs powered by education R&D, and protect our innovation lead—and our national security—for the future.

INTRODUCTION

*"Our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world. … **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. As it stands, we have allowed this to happen to ourselves.**"*

—A Nation at Risk: The Imperative for Educational Reform, 1983[1]

Technology has always determined which country is the leading global power. From Roman roads to British steamships, the most advanced technology has underpinned hard power and, in turn, national security.

For the past 70 years, the U.S. and our friends and allies maintained the undisputed innovation lead. Investments in our technological capabilities during the Cold War paid dividends for decades. But we are in danger of losing our edge.

The warning quoted above from the 1983 report *A Nation at Risk* is even more true today. Faced with the revival of great power competition and a near-peer competitor in China, America must act boldly to maintain our advantage and thus protect our national security.

To do so, we must provide our K-12 students with a strong educational foundation, preparing them to innovate and cultivating the science, technology, engineering, and mathematics (STEM) talent pipeline we need.

To maintain our competitiveness, and national security, we need to educate our children for the jobs of the future.

The challenges facing the U.S. education system are myriad and daunting. However, the momentum behind reinvigorating our innovation ecosystem to compete with China and others—demonstrated in recent legislation such as the CHIPS and Science Act—offers a unique window of opportunity. The U.S. has faced a great power competitor before and met the challenge with bold investments in education and innovation. We must do so again now.

The United States must improve its STEM education specifically for the following reasons:

- The workforce needs and opportunities in STEM fields are growing rapidly, and STEM jobs are critical for our innovation ecosystem.
- This ecosystem boosts our GDP, bolsters our economic security, and underpins our national competitiveness.
- Our national security and defense rely on having critical thinkers on the front lines of technical disciplines like AI, semiconductors, and quantum computing, which are directly relevant to developing the most advanced weapons systems.

Existing methods cannot create the education system we need to compete. Fortunately, research and development (R&D) into education innovations can put more students on the path to success. With new technologies, advancements in the science of learning, and better data, the potential to improve student outcomes is great.

To meet the future demand of STEM jobs, we need to better prepare all our children. We can only accomplish this by investing in education R&D that can lead us to unprecedented advances, a goal that will require a cross-sector coalition, including national security voices, to build momentum for change.

This report examines:

- Which industries will be most important to our national security in the coming years;
- The gaps in our education system for those key industries; and
- Specific recommendations for the federal government and the national security community to improve the STEM workforce pipeline.

The following recommendations—described in detail below—are practical approaches that can collectively move the needle on a stubborn trend and improve our education system. Specifically, the U.S. should:

- **Leverage the National Security Community to Promote Education as a Priority**
- **Utilize the National Defense Authorization Act as a Vehicle for Change**
- **Bolster and Deepen Our Investments in Education R&D**
- **Align Student Learning Pathways with the Skills They Will Need**

FRAMING THE PROBLEM

America is engaging in the global technological competition with an education system that is not fit for purpose—it does not adequately prepare our students. We are no longer keeping pace with other countries, particularly China, in K-12 and higher STEM education outcomes.

According to the National Science Board's 2022 Science and Engineering Indicators, the U.S. **ranked a measly 25th out of 37 Organization for Economic Co-operation and Development (OECD) countries in mathematics literacy**.[2] The 2022 National Assessment of Educational Progress (NAEP) scores—the largest nationally representative assessment of student knowledge in both public and private schools—demonstrated a **seven-point decline in student achievement in mathematics** compared to 2020, the first ever decline in math.[3] Additionally, on the 2018 Program for International Student Assessment (PISA), which gauges the knowledge of 15-year-olds around the world, China topped the charts in math (with a mean score of 591, a level four compared to the U.S. at 478, a level two) and science (China at 590, a level four, and the U.S. at 502, a level three).[4]

This failure at the K-12 level is dangerous and translates into a lack of U.S. students getting degrees and credentials in STEM and a lack of domestic talent for our innovation workforce.[5]

K-12 education provides the foundation for postsecondary STEM majors and careers in STEM. The 2018 Strategy for STEM Education by the National Science and Technology Council showed that **only 20% of college-bound American high school students are ready for STEM college courses**.[6] In 2017, only 21% of computer science majors and 19% of electrical engineering majors at the graduate and postdoctoral level at U.S. universities were American students.[7]

As the 2020 *Industrial Capabilities* report notes, Russia has four times the number of engineers as the United States, and China has eight times as many STEM university graduates.[8]

In addition to preparing students to study STEM fields at the university level, we must also ensure that our K-12 system is building flexible pathways beyond college to prepare students for the job market. A startling analysis conducted by the Burning Glass Institute showed that "only 18% of the credentials earned by K-12 students . . . are demanded by U.S. employers."[9] This disconnect between education and the skills employers need results in a shortage of domestic talent for key industries: for example, more than half of all doctorate holders working in engineering, computer science, and mathematics careers in the U.S. are foreign-born.[10]

The situation is urgent. The United States must take bold actions now to enhance our education system.

WHICH SECTORS MATTER IN THE GLOBAL TECHNOLOGY COMPETITION?

Given America's terrible K-12 outcomes relative to other countries, the U.S. must invest in its human capital. In what areas do we most need a prepared pipeline of talent?

Due to the pace of technological change and innovation, several task force members noted the difficulty in predicting the critical technologies of the future. Therefore, we must prepare our students with core STEM training to equip them with the basic building blocks they will need. Crucially, we must also create a culture of innovation for students, encouraging creativity and flexibility, thus teaching students to be **critical thinkers who are resilient and adaptable in the face of change**. Learning will be a lifetime pursuit as technologies evolve throughout a career.

As ChatGPT, Bard, and other generative AI models have shown, we need to maintain flexibility to adapt to new realities. For example, coding academies have been much in fashion, but soon AI may do most basic coding. Technological breakthroughs will continue to shake up what skills are most vital, but basic STEM knowledge and an innovative culture will remain critical.

Although we cannot precisely foresee which technologies will be the most important, we can make some informed predictions. The key sectors where the U.S. will need a prepared pipeline of talent for the next few decades are:

Semiconductors

Semiconductors are a foundational technology. Known as the "brains of modern electronics," they are the building blocks used in everything from communications and clean energy technologies to AI and quantum computing.[11] Without continued advancements in semiconductor technology, we cannot reach the potential of AI, biotech, quantum computing, and many other future technologies. Simply building new manufacturing facilities (known as fabs) is not enough. We must continue to lead in advanced semiconductor R&D so we can design, build the tools to create, and manufacture the next-generation semiconductors.

Artificial Intelligence (AI)

The National Security Commission on Artificial Intelligence (NSCAI) described AI as a "constellation of technologies" that will have wide-ranging impacts.[12] Like electricity, AI is a multipurpose tool that will "be incorporated into virtually all future technology. The entire innovation base supporting our economy and security will leverage AI."[13] We have barely scratched the surface of AI's potential applications.

Quantum Computing

Quantum computing offers the potential for much more powerful data processing than with conventional computers. Advancements in this field could put sensitive data currently protected by state-of-the-art encryption at risk, in addition to other potential implications for civil and military applications.

5G and 6G

5G and 6G mobile networks are key to everything from autonomous vehicles and the internet of things to precision agriculture systems and remote healthcare. Military applications include improving intelligence, surveillance, and reconnaissance systems; speeding up command-and-control operations; and enabling augmented and virtual reality environments for training.[14]

Biotechnology

Biotechnology is a fast-moving, unpredictable, and potentially dangerous field for future national security. The National Intelligence Council has predicted that by 2040 future biotechnologies could impact genetic modification, computer-human interfaces, DNA-based data storage, synthetic organisms, and more.[15]

Financial Technology (FinTech)

FinTech encapsulates everything from mobile payment platforms to cryptocurrencies. Losing the lead in this area could undermine the U.S. financial system and the effectiveness of U.S. foreign policy tools like sanctions.

These sectors—and those that have not yet been invented—will need talent at all levels, from PhDs to technical trainees. For example, a leading semiconductor fab needs a combination of individuals with necessary skills, including specialized trade workers to build the fabs, trained technicians to operate the manufacturing tools, and highly educated engineers to design new manufacturing technologies, as well as to design and develop the chips.

EDUCATION GAPS

Just as the international race in key technologies heats up, America's education system is cracking at the seams. This is due to a number of interconnected gaps, some of which we highlight below:

STAFFING AND RESOURCE CHALLENGES

Decades of research has shown that teachers are the most important in-school factor in student learning.[16] Teachers' qualifications and levels of experience matter for student achievement.[17] Yet the United States has long struggled with shortages of qualified math and science teachers.

For the 2022-23 school year, 46 states reported a shortage of science teachers and 44 states reported a shortage of math teachers.[18] The National Center for Education Statistics reported last year that nearly half of all U.S. schools had teacher shortages.[19] An August 2022 study found that across all subjects nationwide, at least 163,000 positions were held by underqualified teachers and an additional 36,000 were vacant[20]—**a shortfall of roughly 200,000 qualified teachers.**

In California—home of Silicon Valley and the hub of technology innovation in the U.S.—the shortage of qualified teachers has been particularly severe, with about half of new math and science teachers entering the classroom without having completed preparation to teach their subject.[21]

Meanwhile, the spiraling cost of their own higher education is significantly impacting teachers. The average debt for those earning a bachelor's degree in education is $28,800[22] and $54,180 for a master's degree.[23] Studies show that an individual's student debt is a major disincentive to enter teaching[24] given the lower salaries teachers can expect to earn: on average nearly 25% less than other college-educated professionals.[25] The average teacher lives below the family living wage and is eligible for federal assistance in at least 30 states.[26]

For these reasons, it is challenging to recruit and retain qualified teachers. When there are not enough qualified teachers, the schools with the fewest resources and worst working conditions are left with vacancies and unqualified teachers. As we seek to bolster our supply of qualified teachers, we must incentivize them to teach in the areas with the most need.

LACK OF DIVERSITY, EQUITY, AND INCLUSION IN STEM

Women and people of color have always been underrepresented in the STEM fields. To counteract this, we need to consider access to quality STEM education for these demographics. According to *Inequitable Opportunity to Learn,* a report by the Learning Policy Institute, **"high schools with a high proportion of students of color are less likely to offer advanced mathematics and science courses."**[27] In schools with a high proportion of students of color, only 52% offer calculus (compared to 76% of other schools) and 67% offer physics (compared to 84% of other schools).[28]

This lack of access to advanced coursework widens the achievement gap and hinders our ability to prepare more students to enter STEM-related occupations. As a result of this inequity, we are losing significant and important innovations. The Equality of Opportunity Project reported that "If women, minorities, and children from low-income families were to invent at the same rate as white men from high-income (top 20%) families, the rate of innovation in America would quadruple."[29]

UNDERINVESTMENT IN EDUCATION R&D

The Department of Education is woefully behind other agencies when it comes to R&D investments. The Department of Education's 2023 R&D budget is only $402 million,[30] and its specific R&D arm—the Institute of Education Sciences—has a budget of $807 million.[31] By comparison, the Department of Agriculture's R&D budget is over $3 billion.[32]

Not surprisingly, where other fields, like agriculture, have experienced unprecedented growth and advancement, we have not seen similar advancements in education. To turn the tide, we need new approaches to spur education innovation at scale. We need to shift our mindset around education R&D, assigning it the same level of importance as other areas critical to our national well-being.

LACK OF CREATIVE WAYS TO TEACH STEM

We need to incentivize more students to pursue STEM learning by finding more creative ways to teach it. In the recommendations that follow, we suggest promising pilot programs that can engage students in STEM in new ways.

RECOMMENDATIONS

American students are falling behind their international peers in STEM education due to some of the critical gaps previously outlined. Given the urgency, the national security, technology, and education experts who participated in these workshops brainstormed potential solutions, outlined below. While we were generally aligned on the goals and the need for rapid, creative action, this is not intended to be a consensus document.

LEVERAGE THE NATIONAL SECURITY COMMUNITY TO PROMOTE EDUCATION AS A PRIORITY

Over a decade ago, an Independent Task Force on U.S. Education Reform and National Security, chaired by Condoleezza Rice and Joel Klein, raised awareness of the threat posed by a weak K-12 education system, yet the problem persists today.[33]

Many national security experts are already calling for education reform, especially in the STEM areas. Now we must back our rhetoric with action.

To understand the scale of the resources we are committing to our national security, the 2023 National Defense Authorization Act (NDAA) authorized $847.3 billion for national defense programs across the Department of Defense (DoD) and Department of Energy—a full $45 **b**illion MORE than the Biden administration requested.[34]

Were we to invest that extra $45 billion in U.S. high school STEM education, we could spend an additional $2,900 per high school student.[35] Since the average annual amount spent per pupil is $17,013, this would, in theory, be a 17% increase for every student.[36]

The national security community should actively advocate for appropriate funding and prioritization for U.S. STEM education, both in Congress and in public fora.

UTILIZE THE NATIONAL DEFENSE AUTHORIZATION ACT AS A VEHICLE FOR CHANGE

One avenue for funding mutually beneficial education and national security initiatives is the annual National Defense Authorization Act (NDAA). This bill, passed every year, is still one of the major areas of bipartisan cooperation in Congress and may be an opportunity to expedite key education initiatives that may otherwise face legislative roadblocks.

For example, the 2021 NDAA authorized a grant program to improve STEM education at schools that house Junior Reserve Officers' Training Corps (JROTC) units.[37] Roughly 545,000 JROTC cadets attend 3,400 high schools, so the program could impact the overall 4 million students at those schools.[38] Additionally, JROTC reaches a highly diverse group of students and supports economically disadvantaged populations, presenting an opportunity to impact an important demographic, especially since "68% of these students do not have access to AP computer science in their school."[39] This program needs to be fully funded and scaled.

Other NDAA provisions are strong examples of potential cross-pollination in the education and national security fields. The 2021 NDAA also directed the DoD to incentivize its contractors to support STEM education at the K-12 and postsecondary levels[40] and expanded the geographical reach of the STARBASE youth outreach program, which provides "hands-on, minds-on" experiences for 5th graders to encourage them to explore STEM opportunities.[41] The 2022 NDAA mandated that the DoD assess the benefits and costs of potentially extending the Manufacturing Engineering Education Program to high schools to promote manufacturing career pathways.[42] Additionally, the

most recent 2023 NDAA requires the DoD to develop a "strategy fostering and strengthening the defense innovation ecosystem,"[43] which is an opportunity to increase the role of K-12 partners in that system and include education as a key component of a successful strategy.

As we consider the NDAA each year, we must think creatively about future educational initiatives and prioritize them in this process. For example, we could:

Include Provisions in the NDAA Inspired by a New National Defense Education Act

America has previously risen to the challenge of a strong technological rival. In 1958, the National Defense Education Act (NDEA), passed during the Eisenhower administration, designated $1 billion over seven years to improve education, providing funding for fellowships and loans and bolstering math, science, and foreign language education in K-12 and beyond.[44]

> *"In order to compete long term with the Soviets, the United States responded boldly [to the launch of Sputnik], passing the National Defense Education Act in 1958.…Those targeted investments contributed to technological advantages that the United States enjoyed in the second half of the 20th century. Now, new challenges confront the United States that will require strategic investments in education, much like those investments made over 65 years ago."*
>
> **Mignon Clyburn,** Commissioner, National Security Commission on Artificial Intelligence[45]

In recent years, many in the national security community have advocated for a new NDEA, including in DoD's FY2020 *Industrial Capabilities* report[46] and the National Security Commission on Artificial Intelligence's (NSCAI) final report. Including NDEA-inspired provisions in the National Defense Authorization Act means they have a better chance of getting passed.

The AI commission report offers a robust framework—specifically, it **calls for funding for STEM-focused after-school and summer programs, funding for K-12 STEM teacher training, increased STEM scholarships and fellowships from the National Science Foundation, and the addition of computational thinking and statistics to student testing.**[47] The last point could be accomplished by expanding the National Assessment of Educational Progress to include a STEM assessment focused on computer science or other emerging technology fields.

The original NDEA from the 1950s exemplifies how investments in education at a critical moment in history can yield dividends for decades. Following the bill's passage, the number of students enrolled in college more than doubled from 3.6 million in 1960 to 7.5 million by 1970.[48]

Including the recommendations for the new NDEA in the NDAA improves the chances of getting them passed and implemented. These investments would be a strong response to our current challenges.

Invest in "ROTC for Teachers": Cover Higher Education Costs for Teachers If They Agree to Teach STEM for Three Years

When concerns about shortages of math and science teachers were raised in the 1950s, the NDEA established the **National Defense Student Loan program to provide low-interest federal loans for postsecondary education, especially for those planning to teach K-12 afterwards.** This investment, along with other financial aid programs, **helped the U.S. strengthen its teacher workforce in the 1960s and 1970s** and temporarily ended teacher shortages.

But when these programs were dramatically reduced or discontinued during the Reagan administration, teacher shortages returned.[49]

To increase the supply of well-prepared math and science teachers, the federal government could fund a **service scholarship or loan forgiveness program to fully cover postsecondary education costs for those who commit to teach at the K-12 level for at least three years.** (After three years, teachers are more likely to stay in the profession and positively impact student outcomes.)[50] Such a program could be structured to provide even greater incentives for recruits who teach in high-need locations (e.g., rural and low-income schools). This is similar to the promise the U.S. makes to young cadets and midshipmen in the ROTC program.

While the federal government offers some small similar programs (e.g., the TEACH grant, Teacher Loan Forgiveness), they have dwindled in value and do not adequately meet our recruitment needs. Given the growing mismatch between the costs of becoming a teacher and the opportunity costs of remaining one, a targeted service scholarship or loan forgiveness program could be a cost-effective strategy to recruit and retain a well-prepared math and science teacher workforce.

There is already interest in Congress to address shortages in high-need areas; legislation has been introduced to update the Teacher Loan Forgiveness Program such that the federal government would pay teachers' monthly loan payments as they teach in high-need schools and then retire their debt after a set number of years of service.[51] **To get these programs over the finish line, we could include them in the NDAA.** Such an approach could improve teacher recruitment and retention.

Use Existing Department of Defense STEM Education Programs to Better Effect

The federal government is operating on the 2018 STEM Education Strategic Plan, a five-year blueprint to "build strong foundations for STEM literacy; increase diversity, equity, and inclusion in STEM; and prepare the STEM workforce for the future."[52]

The DoD itself has made relatively small investments to support this strategic plan, spending $222 **m**illion in FY 2022[53] on STEM education across 11 investments[54]—or about 0.03% of its $777 billion budget that year.[55]

The DoD should prioritize and scale these programs in the NDAA to increase their impact and find more opportunities to build out the STEM components of the Pentagon's own talent pipeline.

BOLSTER AND DEEPEN OUR INVESTMENTS IN EDUCATION R&D

As mentioned above, research into and development of new, better ways to teach science and math will be critical for improving our STEM education in the U.S., yet we are drastically underinvested in it. The following are ways we can strengthen our existing investments in education R&D, as well as improve the mindset surrounding it.

Create and Properly Fund the National Center for Advanced Development in Education

Recently, the U.S. has taken positive steps toward creating a DARPA-like entity for education. The Institute of Education Sciences (IES)—the semi-autonomous R&D agency at the Department of Education—received $30 million to pilot DARPA-like methods in its work. While this is a promising start, we must do more to realize the potential of an ARPA-ED.

A full ARPA-ED would fund informed-risk, high-reward projects developed by industry, universities, researchers, or other innovative organizations. This requires structures that do not currently exist at IES, including greater flexibility in hiring and more autonomy to fund projects outside of IES' standard peer review process.

Last year, the NEED Act proposed the creation of an ARPA-ED and named it the National Center for Advanced Development in Education (NCADE).[56] NCADE would be a new center at IES **dedicated to finding new ideas and approaches rarely tackled by the market**. NCADE could invest in innovations like voice recognition software to screen for learning disabilities, digital assistants that motivate students, virtual reality programs to help visualize data, and portable learner profiles with personalized education plans for students, among other things. These technologies could be game-changing.

Making NCADE a reality would require a reintroduction of the NEED Act—which failed to pass last year—and an investment of at least $500 million,[57] a small amount for a critical program.[58]

Find New Ways to Teach STEM

Getting students excited about STEM at a younger age will be key to creating a stronger pipeline of STEM talent. An ARPA-ED could find new programs to make STEM education more enticing to younger students, for example by using virtual reality (VR) to engage different learning styles.

One creative idea is Dreamscape Learn, a collaboration between Arizona State University (ASU) and Dreamscape Immersive that provides an immersive virtual learning experience for biology students. Students visit the "Alien Zoo," an intergalactic wildlife sanctuary, to learn basic biology. Outcomes were impressive: students using the VR **"earned higher median lab scores than did students [that didn't use the VR] across all levels of gender, underrepresented minority status, and Pell grant eligibility status,"** according to a 2022 ASU report.[59]

Given different learning styles, we must engage students in STEM outside of the classroom as well. Opportunities like summer coding camps or robotics competitions can entice students with hands-on experiences. One example is the CyberPatriot program, a national competition created by the Air and Space Forces Association to engage middle and high school students in cybersecurity.

Moreover, with the advent of generative AI, there is a "Sputnik moment" to democratize access to the best teaching tools. We can place in the hands of every learner, student, parent, and guardian the most advanced adaptive learning tools the world has ever known.

For example, we know that mastering math is perhaps the key building block to earning a STEM degree, but 38% of 8th graders are not performing at grade level.[60] If we can intervene early with adaptive learning tools that teach students based on their learning style, we can put more students back on track for STEM pathways. Personalized teaching through AI already exists—Arizona State University's Math, Computer Science, and Statistics Accelerator is one example and the Khan Academy's Khanmigo is another. We must leverage this technology to create more efficient processes, **freeing up teachers to do more of the things that only teachers can do**. An ARPA-ED would support innovations like these.

Improve Data Collection and Sharing to Promote Greater R&D Outcomes in Education

As with all industries, the education R&D sector can only harness breakthroughs powered by generative AI with high-quality, large data sets that tell us which interventions work and which do not. Unfortunately, such data sets are scarce in education. We need to make two sources of large data sets more widely available: the National Assessment of Educational Progress (NAEP) data and the Statewide Longitudinal Data Systems (SLDS).

Since 1969, NAEP has measured student achievement across the country in math, reading, science, writing, arts, and civics. It holds hundreds of thousands of examples of student work coupled with detailed contextual information about students, their schools, and their communities. We need to mine that vast data repository to discover better ways to improve student learning.

Likewise, the SLDS is a network of systems that contains high-quality data for states and educators to track outcomes from early education through to the workforce. However, the network needs modernization and will probably require another $1 billion over the next few years to update.[61] Modernizing the technological infrastructure of SLDS and using technology to link education data to other data systems (for example, labor market information) would be groundbreaking.

In freeing data from NAEP and the SLDS network, we would need to protect the privacy of student information. But modern privacy protection technology can minimize the risks while allowing greater use of these data sets to identify how to improve student learning outcomes.

Strengthen National Science Foundation Programs Supporting Innovation in K-12 Education

The CHIPS and Science Act authorized the creation of "Centers for Transformative Education Research and Translation" to scale up K-12 education innovations. These centers will support collaboration between the National Science Foundation (NSF), the Department of Education, and others, using proven solutions to create better student outcomes.[62]

One example is the National Artificial Intelligence Research Institutes—led by IES and NSF—that use AI to improve learning. Partners, including the Department of Defense and the Department of Homeland Security, have invested $500 million.[63] Two institutes have been funded so far by IES and NSF—the first, at the University at Buffalo, uses AI to assist kids with speech and language processing challenges, and the second, at the University of Illinois, uses AI to improve skills like persistence and collaboration.[64]

We must encourage existing collaborative efforts and find new opportunities for partnerships—for example, between the IES and the new Directorate for Technology, Innovation, and Partnerships (TIP) at NSF. Specifically, Congress could call for TIP and IES to support education R&D programs that can improve student learning.

Shift the Mindset Around Education R&D

For the education R&D already underway, we need to rethink the balance between research and development. Traditionally, the Department of Education has focused most of its R&D funding on research, for example by evaluating instructional models. This is important, but we also need to invest in *developing* successful programs. In recent years, Congress and the Department of Education have funded new development-focused initiatives like the Education Innovation and Research (EIR) programs.[65] One example of an EIR-funded program is the ASSISTments tool, an AI-enabled math tutoring platform that provides teachers with valuable data to help struggling students early. The ASSISTments tool led to a 75% increase in learning over two years.[66] Also funded by EIR (when it was called Investing in Innovation), the Diplomas Now program instituted early warning systems to monitor indicators like math proficiency to reduce drop-out rates.

In other words, these investments focus on *developing* new learning models and programs rather than researching how education functions. Congress could specifically direct the Department of Education to focus additional EIR grants on STEM projects that can be scaled.

In addition to rethinking the balance of research and development in education R&D, we also need to break down siloes by **actively sharing research from national security R&D that can improve learning.** The research already being done at DARPA, national labs, universities, and other R&D settings should be put to use in the educational context. One successful example of applying DARPA's research to education is the DARPA Education Dominance Program, which produced an advanced digital tutor that far outperformed the classroom experience and was on par with 1:1 tutoring.[67]

ALIGN STUDENT LEARNING PATHWAYS WITH THE SKILLS THEY WILL NEED

Ensure that K-12 Education Is Included in Competitive Applications for Federal Funding

Enormous funding is going to maintaining America's global tech lead, from the CHIPS Act to Build Back Better, and we could use some of these vehicles to support STEM education. For example, the CHIPS Act Notice of Funding Opportunities for commercial fabs says: "Strong applications will also . … [e]ngag[e] with educational institutions at all levels … , including commitments to work with K-12 institutions and develop and strengthen career and technical education."[68]

We should require applicants for federal funding to have K-12 partners, especially for any regional economic development plans. These plans will underpin economic competitiveness in strategic sectors; not developing the workforce to deliver on the promise of these investments would be a massive mistake. For example, the Recompete program—a Department of Commerce initiative to support the workforce in distressed communities—should include longer-term K-12 investments that will help prevent future workforce gaps. Education partners should be at the table in these discussions so that short-term solutions to regional economic distress are paired with longer-term investments in the workforce pipeline.

Making sure that education partners are included in any competitive application process for funding will help link K-12 education to workforce needs.

Skills and Credentialing for National Competitiveness

Finally, the U.S. sometimes over-focuses on college, which is not always the most effective way to teach key skills.

For example, with over 500,000 unfilled cybersecurity positions[69] and a projected 2.1 million unfilled manufacturing jobs by 2030,[70] the time to link our workforce development directly with our K-12 education system—rather than biasing in favor of college—is now.

One way would be to **scale up our registered apprenticeship** programs certified by the Department of Labor and ensure they are connected to the K-12 level.

Funding and interest in apprenticeships has increased in the U.S. in the past decade, but in 2020, the share of registered apprentices in the labor force was still only 0.3%.[71] The rates in countries like Australia and England are around 2%.[72]

We must include more flexible pathways for students to attain the skills they need outside of college. Apprenticeships for America recommends a model in which federal funding goes to intermediary organizations that stimulate employers to start and expand apprenticeship programs, with the funding based on each apprentice placed with employers. Congress would provide funding up to a designated amount to the Office of Apprenticeship to manage and audit the pay-per-apprentice model.

Clear standards are important. **We need to establish clear federal guidelines as to which career and technical education (CTE) training programs get funded, basing the program's value on the match between the skills for which workers are trained and the real needs of strategic industries.**

We need to define which skills matter most for national competitiveness in target sectors. States and local areas will have specific needs, but overall, four factors should drive this determination:

1) the level of demand and degree of shortage;
2) upward mobility and wages for workers;
3) projected demand growth and estimated value for the sector; and
4) opportunities to boost workforce equity.

Once we have established which skills are essential, we can ensure that CTE training—from the K-12 level through to the workforce—aligns with the jobs that are in demand, well paying, fast growing, and strategic.

Federal guidelines will offer employers a standard assessment of capability, signal to learners what career paths to pursue, inform education institutions about how to prepare learners for high-value jobs, and standardize qualifications around a single evaluation that offers transparency into the strengths and weaknesses in our talent pipelines.

To take it a step further, the federal government could then provide tax credits for companies investing in CTE programs for their workers in one of the target sectors for national competitiveness. The tax credit could require companies to have a partner at the K-12 level and a plan to create a pipeline for students to enter that industry. The government would need to determine which credentials are eligible for the tax credit to ensure it is incentivizing only the most essential skills for our national security.

CONCLUSION

We cannot continue to watch as our education system deteriorates, failing our students and weakening our nation's technological capabilities. Education R&D, in particular, can be an exciting catalyst for breakthroughs in K-12 education that can help all students unlock their potential. We must commit more time, resources, and energy to this piece of the innovation puzzle to ensure we are not wasting our investments in other areas—from manufacturing facilities to industrial capabilities.

The decisions we make today will have impacts for years to come. We must strengthen our education system and prepare our students for the realities of the global technological competition. Our future depends on it.

SIGNATORIES

Dan Correa
Chief Executive Officer
Federation of American Scientists

Chris Howard
Executive Vice President and
Chief Operating Officer
Arizona State University

Anja Manuel
Executive Director
Aspen Strategy Group and
Aspen Security Forum

Bruce Andrews
Chief Government Affairs Officer
Intel

Doug Beck
Director, Defense Innovation Unit,
Senior Advisor to the Secretary of Defense;
Previously Vice President, Apple, Inc.

Arthur Bienenstock
Special Assistant to the President for
Federal Research Policy
Stanford University

Jean-Claude Brizard
President and CEO
Digital Promise Global

Dan Brunner
Co-Founder and
Chief Technology Officer
Commonwealth Fusion Systems

Breanna Carpenter
Assistant Director
Office of the Chief Operating Officer,
Arizona State University

Peter Cowhey
Dean and Qualcomm
Professor Emeritus
School of Global Policy and Strategy
UC San Diego

Ryan Craig
Managing Director, Achieve Partners
Author of the upcoming *Apprentice Nation: How the "Earn and Learn" Alternative to Higher Education Will Create a Stronger and Fairer America*

Linda Darling-Hammond
President and CEO
Learning Policy Institute

Kristina Francis
Executive Director
Jobs for the Future, JFFLabs

Caitlin E. Kalinowski
Board Member
Axon

Niamh King
Director
Aspen Strategy Group and
Aspen Security Forum

Tara Kini
Chief of Policy and Program
Learning Policy Institute

Emily Lawrence
Aspen Strategy Group Fellow
Aspen Strategy Group

Edlyn Levine
Chief Science Officer
America's Frontier Fund

Dan Lips
Head of Policy
Foundation for American Innovation

Gilman Louie
Chief Executive Officer
America's Frontier Fund

Mark Schneider
Director
Institute of Education Sciences

Matt Sigelman
President
The Burning Glass Institute

Dale Swartz
Partner
McKinsey & Company

John Whitmer
Senior Fellow
Institute of Education Sciences

H.S.-Philip Wong
Willard R. and Inez Kerr Bell
Professor
School of Engineering,
Stanford University

This report seeks to capture the essence of participant conversations, but individual participants may not agree with every aspect of the report. Rather, in affixing their name as a signatory, a participant is signaling support for the overarching concept of the series and the broad outcomes discussed herein.

SIGNING STATEMENTS

This excellent report is an important contribution to our national discussion. I would add to it that vigorous support for, and innovation in, our PhD education focused on basic research remains essential to American progress and innovation.

Peter Cowhey
Dean and Qualcomm Professor Emeritus,
School of Global Policy and Strategy, UC San Diego

If the nation fails to address the financial barriers to higher education faced by a high proportion of our youth, then the actions recommended in the report will be insufficient to gain the talents of many young people in the lower economic strata.

Arthur Bienenstock
Special Assistant to the President
for Federal Research Policy, Stanford University

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2300 N Street, NW | Suite 700 | Washington, DC 20037 | aspeninstitute.org